

COVER SHEET Access 5 Project Deliverable

Deliverable Number: CCA010

Title: Cooperative Collision Avoidance Technology Demonstration Data Analysis Report

Filenames: CCA010 CCA Technology Demonstration Report FINAL2.doc

CCA010_CCA Technology Demonstration Report_Appendices_A-E CCA010_CCA Technology Demonstration Report_Appendix_G CCA010_CCA Technology Demonstration Report_Appendix_F

Abstract: This report details the National Aeronautics and Space Administration (NASA) Access 5 Project Office Cooperative Collision Avoidance (CCA) Technology Demonstration for unmanned aircraft systems (UAS) conducted from 21 to 28 September 2005. The test platform chosen for the demonstration was the Proteus Optionally Piloted Vehicle operated by Scaled Composites, LLC, flown out of the Mojave Airport, Mojave, CA. A single intruder aircraft, a NASA Gulf stream III, was used during the demonstration to execute a series of near-collision encounter scenarios. Both aircraft were equipped with Traffic Alert and Collision Avoidance System-II (TCAS-II) and Automatic Dependent Surveillance Broadcast (ADS-B) systems.

The objective of this demonstration was to collect flight data to support validation efforts for the Access 5 CCA Work Package Performance Simulation and Systems Integration Laboratory (SIL). Correlation of the flight data with results obtained from the performance simulation serves as the basis for the simulation validation. A similar effort uses the flight data to validate the SIL architecture that contains the same sensor hardware that was used during the flight demonstration.

Status:

SEIT-Approved

Limitations on use: This document represents the analysis of the Access 5 Collision Avoidance Work Package. It contains analysis of flight demonstration data collected to validate the CCA Performance Simulation only. Unfortunately the project ended before the validation of the Performance Simulation could be completed. This validated simulation was intended to be the source for deriving the CCA Performance Guidelines found in the CCA Functional Requirements Document (CCA002).

The flight demonstration utilized existing systems and Access 5-developed components in a test-expedient architecture and, as such, should not be used to infer conclusions about the applicability of either TCAS-II or ADS-B as an element of a UAS collision avoidance system.

NASA ACCESS 5

Cooperative Collision Avoidance Technology Demonstration Data Analysis Report

Prepared by:



NASA ACCESS 5 Work Package 2, CA Team

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project

Cooperative Collision Avoidance (CCA) Tech Demonstration Data Analysis Report

Executive Summary

The Access 5 Project Office sponsored a cooperative collision avoidance (CCA) technology demonstration for unmanned aircraft cooperative collision avoidance systems from September 21 to September 28, 2005. The objective of these flights was to collect data to be analyzed by the Cooperative Collision Avoidance Work Package and used to refine and validate the performance simulation and functional requirements that were previously developed.

The test platform selected was the Proteus Optionally Piloted Vehicle (OPV) operated by Scaled Composites, LLC from the Mojave Airport in Mojave, California. Proteus was manned by two on-board pilots, but was controlled by a ground pilot in the Air Vehicle Control Station (AVCS) during test points. For this demonstration, Proteus was equipped with both Traffic Alert and Collision Avoidance System-II (TCAS-II) cooperative collision sensors and Automatic Dependent Surveillance-Broadcast (ADS-B) situational awareness enhancement technology. A single intruder aircraft used during the demonstration, a NASA Gulfstream III (G-III) operating from Edward AFB, CA, was also equipped with TCAS-II and ADS-B.

Following the series of six flights, the CCA Work Package processed and analyzed aircraft and CCA sensor system data to characterize the CCA systems in terms of data latency, missed error rates, pilot response, and sensor position error. Selected data parameters recorded on both aircraft and the AVCS were extracted from over 9 GB of data collected during the flights and stored in MS Access databases for analysis.

The CCA Work Package used the data to refine and validate the CCA Performance Simulation. Selected flight test runs were replicated in the simulation and CCA system component models adjusted to ensure that aircraft flight characteristics and sensor performance accurately matched data collected in flight. Validation of system characteristics was performed to the extent possible, given accuracy and availability of the data. Extensive use of the simulation will be necessary to provide a body of evidence supporting values for many of the performance specifications detailed in the CCA Functional Requirements Document.

The CCA Performance Simulation is available for limited distribution as deliverable CCA008-Rev2. The Functional Requirements document is available for unlimited distribution as deliverable CCA002-Rev6. The sections that follow constitute the CCA Technology Demonstration Data Analysis Report, deliverable CCA010. This document presents the CCA perspective of the technology demonstration, data processing and analysis, simulation validation, lessons learned, and conclusions.

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1 Introduction

1.1 Document Organization

This document is organized into the following sections and appendices:

- Section 1 Introduction. States the background and purpose of the technology demonstration and its role in the Access 5 program.
- Section 2 Technology Demonstration Architecture. Lists the hardware and software utilized in the testing process and identifies the data collection points.
- Section 3 Simulation Architecture. Describes the performance simulation and Systems Integration Lab (SIL). These are both being validated by the technology demonstration.
- Section 4 Test Conduct. Explains how the test matrix was developed and used to gather the flight test data. Also summarizes the sorties and any issues that arose during the technology demonstration.
- Section 5 -- Data Processing. Describes the methods developed and employed to process the recorded data, as well as assessments of the data recorded at each point.
- Section 6 Analysis and Results. Discusses the data processing methodology and timeline issues, and presents a refined view of the flight test data. Analyzes the sensor errors, latency issues, and validation of the performance simulation and SIL.
- Section 7 Summary and Conclusions. Provides a recap of the principal results and issues arising from the technology demonstration, as well as lessons learned for future UAS collision avoidance investigations.

Section 8 – Definitions and Acronyms. A glossary of terms used throughout the report.

Appendix A – CCA Objectives to Data Analyses Mapping

Appendix B - *Data Files and Parameters*

Appendix C – Processed Data Structures

Appendix D – Data Analysis Plots, 'Truth' Position

Appendix E – Data Analysis Plots, TCAS Track

Appendix F - Sensor Timelines

Appendix G – Simulation Validation Plots

1.2 Background

Access 5 is a national program sponsored by NASA with participation by aerospace industry members, the Federal Aviation Administration (FAA), and the Department of Defense (DOD). Headquarters for this effort is the NASA Access 5 Project Office, located at NASA Dryden Flight Research Center in Edwards, CA. The goal is to enable civil High Altitude Long Endurance (HALE) Unmanned Aircraft Systems (UAS) to routinely operate in the National Airspace System (NAS) as safely as manned aircraft while minimizing any adverse impact on the existing system. Further objectives of Access 5 include assisting in the development of UAS policies and procedures, demonstrating that all requirements are reasonable and achievable, and identifying infrastructure to promote a robust civil market for HALE UAS.

Operation of a UAS in the NAS requires that the aircraft perform a set of functions that not only meet mission objectives, but also provide a level of safety equivalent to that of current manned

aircraft operations. A critical element of these safety functions is to sense and avoid other traffic in the airspace. Manned aircraft operating in the NAS have a low risk of mid air collision due to a multilayered approach to collision avoidance. These layers consist of operational procedures, Air Traffic Control services, on-board collision avoidance systems, and see and avoid as the last level.

1.3 CCA Functional Requirements

To help determine the policies, procedures, and requirements for safe, routine UAS operation in the NAS, the CCA work package established a comprehensive set of functional requirements and performance guidelines for a HALE UAS that is capable of reliably detecting cooperative aircraft and providing the necessary situational awareness information and maneuver guidance to a UAS pilot. These requirements are captured in the CA Functional Requirements Document (CCA002_Functional Requirements Document_Rev6), which is available for unlimited distribution.

1.4 CCA Simulation

Three sources have been considered to support evaluation and validation of the CCA functional requirements: existing data, simulation, and flight test. The existing data sources that have been evaluated have been found to be missing elements of the system architecture or lacking essential parameter detail in the data that was recorded. Many previous tests addressing collision avoidance were conducted without a remote operator and, as such, are missing critical elements required to assess the CCA functional requirements. Programs such as NASA's ERAST (Environmental Research Aircraft and Sensor Technologies) demonstrated all of the UAS elements; however, ERAST tests were conducted as a demonstration, and only end-to-end performance data was recorded. Many contributing elements of the system were not individually recorded or were recorded at a data rate insufficient for the purposes of evaluating the CCA functional requirements. The extent of flight testing required to generate sufficient data to analyze requirements precludes that from being a viable option under this program.

The CCA work package elected to use simulation as the primary tool to establish and validate the functional requirements that are laid out in the aforementioned CA Functional Requirements Document (FRD). This CCA Performance Simulation is available, under limited distribution, as deliverable CCA008-Rev2. It was developed to reproduce and analyze a variety of encounter scenarios involving UAS operations in the NAS. The results of this analysis will be used to support safety analyses, refine performance guidelines in the FRD, and assist the FAA in establishing UAS certification standards. Furthermore, the simulation will aid manufacturers in developing future collision avoidance systems for unmanned aircraft. Additionally, a Systems Integration Lab (SIL) was also developed to provide additional simulation opportunities by examining the real-time interactions of actual flight hardware with the simulated aircraft and environment.

1.5 CCA Flight Demonstration

Understanding that the simulation results will be only as good as the fidelity of the simulation, a technology demonstration program was developed to collect detailed flight data for existing collision avoidance technologies during anticipated UAS encounters with other aircraft. The

data was used to validate the CCA Performance Simulation and the SIL through comparison of modeled aircraft and sensor performance with the flight data.

Development of the flight demonstration objectives was based on the CCA Objectives, approved on 22 March 2005 and shown in Table 1. There are six collision avoidance general test objectives that are further divided into Specific Test Objectives. While the expectation is that most of these objectives will rely on the simulation results, the flight demonstration was necessary to validate the simulations and also provide additional data to meet the CCA Objectives themselves.

Table 1. CCA Objectives

CCA		
Objective	CCA Objective Description	
Label	CEA Objective Description	
CGTO-1	Demonstrate the ability to detect cooperative traffic and provide situational awareness to the ROA pilot.	
STO-1.1	Determine the detection range and Minimum Detect Time provided by	
	the CCA subsystem.	
STO-1.2	Determine the effective azimuth Field-of-Regard and azimuth accuracy of the CCA subsystem	
STO-1.3	Determine the effective elevation Field-of-Regard and elevation accuracy of the CCA subsystem.	
STO-1.4	Demonstrate the capability of the CCA subsystem to detect multiple threat aircraft.	
CGTO-2	Demonstrate the ability to track the detected cooperative traffic and provide position information to the ROA pilot.	
STO-2.1	Demonstrate that the time and position information of cooperative aircraft is tracked and presented to the ROA pilot.	
STO-2.2	Demonstrate that tracks of multiple threat aircraft are presented to the ROA pilot.	
STO-2.3	Determine the track accuracy of the time and position information collected on the cooperative threat aircraft.	
CGTO-3	Demonstrate the ability to determine collision potential with detected cooperative traffic and provide notification to the ROA pilot.	
STO-3.1	Observe the information presented to the ROA pilot that conveys collision potential.	
STO-3.2	Demonstrate the utility of the CCA subsystem alert that notifies the ROA pilot of a potential collision threat.	
CGTO-4	Demonstrate that the CCA subsystem provides information in sufficient time for the ROA pilot to initiate an evasive maneuver to avoid collision.	
STO-4.1	Demonstrate that the CCA subsystem alarm is provided in sufficient time for the ROA pilot to initiate an evasive maneuver.	
STO-4.2	Demonstrate the utility of a CCA subsystem recommended evasive maneuver.	
CGTO-5	Demonstrate an evasive maneuver that avoids collision with the threat aircraft.	
STO-5.1	Determine the time required for the ROA pilot to perform an evasive maneuver after the CCA subsystem has notified the ROA pilot of a potential collision.	
STO-5.2	Demonstrate that the evasive maneuver is within the performance limitations of the ROA.	
STO-5.3	Demonstrate that the evasive maneuver resolves the collision threat without creating another collision threat with nearby aircraft.	
CGTO-6	Demonstrate the ability to assess the adequacy of the maneuver and determine that the collision potential has been avoided.	
STO-6.1	Determine that the evasive maneuver maintains separation from the threat aircraft.	
STO-6.2	Demonstrate that the ROA pilot can determine when the ROA is clear of conflicting traffic.	

With selection of simulation as the primary tool to establish functional requirements, the focus of the flights was on collecting data to validate the simulation. A set of Flight Demonstration Specific Test Objectives (FSTO), Table 2, was derived from the CCA Objectives to guide the planning of the technology demonstration. Each of the FSTOs directly supports validation of the performance simulation for use in determining requirements and guidelines specified in the Collision Avoidance CGTOs and STOs.

Table 2. Flight Demonstration Specific Objectives

Objective	Objective Description	
Label		
FSTO-1	Collect data to validate CA sensor models.	
FSTO-2	Collect data to validate link affect models on the transmission of CA sensor data.	
FSTO-3	Collect data to validate the CA display.	
FSTO-4	Collect data to validate operator response to the CA display.	
FSTO-5	Collect data to validate link affect models on the transmission of operator	
	evasion commands to the vehicle.	
FSTO-6	Validate the vehicle model during an evasion maneuver.	
FSTO-7	Collect data to validate the resulting miss distance between the UAS and	
	intruder during a collision avoidance scenario.	

As the technology demonstration data was processed, feasibility of meeting the CCA Objectives via analysis of the technology demonstration data was assessed. A matrix mapping the flight demonstration objectives to the analyses described in Section 6 is contained in Appendix A.

2 Technology Demonstration Architecture

The technology demonstration architecture, shown in Figure 1, consisted of two principal elements, the Proteus (Host) aircraft and the Air Vehicle Control Station (AVCS).

The sensors selected for the flight demonstration were the Traffic Alert and Collision Avoidance System (TCAS-II) and the Automatic Dependent Surveillance – Broadcast (ADS-B) system. TCAS is currently used in the NAS for collision avoidance advisories to the onboard pilot, and ADS-B was recently introduced for traffic surveillance.

Each of the elements in the demonstration also contained instrumentation to record data obtained from the CCA sensors and flight navigation systems, so that 'truth' position data could later be compared to the sensor data. Details of the elements are presented in the subsections below.

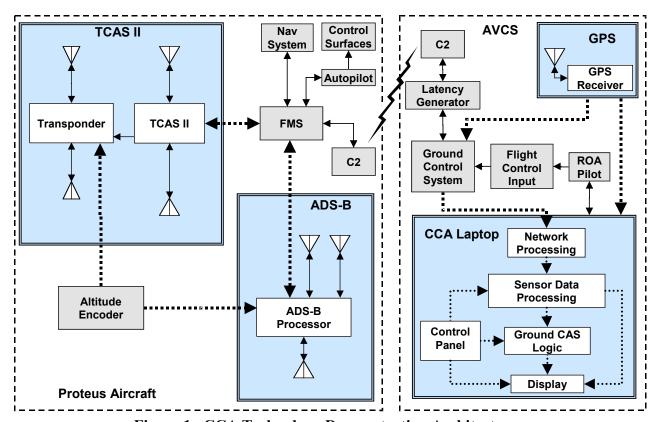


Figure 1. CCA Technology Demonstration Architecture

2.1 Aircraft

Aircraft used in the technology demonstration consisted of the Scaled Composites Proteus and a Gulfstream G-III owned by NASA. The Proteus served the role of the ownship, or host, UAS, while the G-III served the role of the intruder.

2.1.1 Proteus (Ownship/Host)

Scaled Composites, LLC provided a Proteus Optionally Piloted Vehicle (OPV) equipped with TCAS-II and ADS-B subsystems. Proteus (Figure 2) is a twin turbofan high altitude multimission aircraft powered by Williams International FJ44-2E engines. It is designed to carry payloads in the 2000 lb. class to altitudes above 60,000 feet and remain on station up to 14 hours.



Figure 2. Proteus OPV

Proteus was modified for the CCA technology demonstration by installing the TCAS-II and ADS-B sensor systems and by incorporating software in the Flight Management System (FMS) to collect and format traffic data so it could be included on the communication link used for aircraft control. The other equipment on the aircraft during this test is the standard equipment on the aircraft. Proteus was manned during all testing with a pilot and a co-pilot. The autopilot was employed to guide the aircraft through the encounter scenarios. However, the pilot and co-pilot had the ability to assume command of the aircraft at any time deemed necessary. The flight crew was provided by Scaled Composites and complied with FAA regulations.

2.1.1.1 CCA Sensors

The Proteus OPV was modified to include a TCAS-II processor, control panel, directional antenna, VSI/TRA display, Mode S diversity transponder, RCZ transponder, and Mode S transponder Antenna. An ADS-B processor, omni antenna and GPS antenna were also installed.

2.1.1.1.1 TCAS

The TCAS II hardware selected for this architecture is the ACSS TCAS 2000 suite. The processor in this suite of equipment, the ACSS RT-951 receiver/transmitter, contains dual processors that implement the surveillance and collision avoidance functions. The Mode S transponder, ACSS RCZ-852, implements all currently defined Mode S functions. Four antennas are used in the architecture to provide the omni-directional Mode S data link (top and bottom) and directional TCAS signal sensing from positions on both the upper and lower fuselage. The safety pilot in the aircraft interfaced with this equipment through a transponder control panel. Aural TCAS commands and the Vertical Speed/Traffic Indicator (VSI/TRA), which displays traffic advisories and TCAS climb/descend commands resulting from TCAS resolution advisories (RA), were implemented on board the aircraft for use by the safety pilots during the test runs.

2.1.1.1.2 ADS-B

The ADS-B equipment selected for this architecture was the Garmin GDL 90 Universal Access Transceiver (UAT) with a WAAS GPS sensor for high position accuracy and integrity. It is designed to transmit, receive, and decode ADS-B messages via a 978 MHz broadband data link certified to support a broad range of ADS-B services in manned aircraft. The ADS-B installation did not include a display in the aircraft.

2.1.2 G-III (Intruder)

The intruder aircraft was chosen to provide closure velocities representative of the majority of aircraft that currently operate above FL430. NASA Dryden Flight Research Center provided a Gulfstream III (G-III) for these tests (Figure 3). This aircraft was manned by NASA personnel and flown in accordance with FAA and NASA regulations.



Figure 3. G-III Intruder Aircraft

2.1.2.1 CCA Sensors

Since the G-III was previously equipped with a TCAS system, the only equipment added to the aircraft was a Garmin GDL-90 Universal Access Transceiver for ADS-B.

2.1.2.1.1 TCAS

The TCAS hardware on the aircraft comprised a Honeywell RT-951 receiver/transmitter with dual processors to implement the surveillance and collision avoidance functions and a Rockwell Collins TDR-94D Mode-S transponder. Two Honeywell AT-910 antennas provided directional information, while the transponder used the Sensor systems S65-5366-2L antennas. Two Honeywell VSI/TRA displays were installed in the cockpit for displaying traffic advisories and TCAS climb/descend commands resulting from TCAS resolution advisories (RA).

2.1.2.1.2 ADS-B

The ADS-B equipment selected for the G-III was the same model Garmin GDL 90 Universal Access Transceiver (UAT) used in the Host aircraft (Section 2.1.1.1.2). It used existing omnidirectional antennas to broadcast and receive ADS-B information. Like the Proteus, no display was installed in the aircraft.

2.1.2.2 Instrumentation

The existing instrumentation system was used to record airborne flight parameters. The TCAS and ADS-B data was not recorded on-board; therefore, no special software was required to collect sensor data.

2.2 Air Vehicle Control Station (AVCS)

In addition to the Proteus aircraft, Scaled Composites also provided the AVCS with existing air-to-ground communications, command and control (C2) link, ground pilot, pilot controls, and

Ground Control System for processing and recording data received from the aircraft. To meet CCA test requirements, Scaled Composites also provided a communications latency module that delayed receipt and transmission of C2 messages to simulate beyond-line-of-sight (BLOS) transmission delays.

2.2.1 Ground Control System (GCS)

Proteus was controlled remotely via the Ground Control System (GCS). Using the display from a single desktop computer, the UAS pilot monitored system health and navigation/situational awareness. The UAS pilot also had the ability to command and control Proteus from the GCS by using the display, mouse, and keyboard to issue commands that control the vehicle through the onboard flight management system. The GCS also recorded data transmitted from and to the aircraft.

2.2.2 Flight Control Inputs

Vehicle control was accomplished through keyboard and mouse inputs. GCS software was developed to provide a selection of discrete climb/descent rates for the pilot to select when the CCA system generated a climb/descend recommendation. The pilot would select the desired rate from the display and then send the command to the aircraft via the C2 link with a single mouse click.

2.2.3 Latency Generator

FSTO-2 called for collection of data relative to transmission delays between the aircraft and ground station. Because all flight testing was to be accomplished within line of sight, a software module was required to extend, or delay, the time for both uplink and downlink transmissions, thus emulating BLOS data transmissions. Since both downlink and uplink commands were to be delayed, the software module was developed by Scaled Composites and implemented in the GCS.

2.2.4 CCA Laptop

For the technology demonstration, the CCA Laptop only used the Collision Avoidance System (CAS) algorithms and CCA display features of the Common Tool (CT). The laptop was installed in the AVCS beside the GCS as a separate display. The pilot reacted to CCA information provided on the CCA Laptop display and responded through inputs to the GCS. An interface between the GCS and the CCA Laptop was developed to pass sensor data from the Proteus to the CT. Figure 4 shows the CCA Display which was designed to mimic TCAS-II displays, and to provide Vertical Speed Indicator (VSI) guidance as well as aural advisories whenever the integrated CAS algorithm determined that a maneuver was necessary.



Figure 4. Common Tool Display

2.2.5 UAS Pilot

The Proteus OPV was controlled remotely from the GCS located at the Scaled Composites facilities in Mojave, CA. The ground pilot was provided by Scaled Composites and was fully qualified in the aircraft. The Test Conductor handled radio communications between the GCS and aircraft to allow the ground pilot to focus on CCA test objectives. A limited number of test participants were also present in the AVCS to control test operations and for manual data recording.

2.2.6 Command and Control (C2) Link

Scaled Composites provided the C2 link for the CCA flight demonstration. In addition to adding the sensor parameters to the data packets, the communication link was modified mid-way through the flight demonstration to improve the C2 link availability. The system operated on a consumer band that includes cordless phones and other wireless products. On the early flights in the demonstration, frequency hopping often resulted in use of frequencies with significant interference. The modifications limited the hopping to frequencies with little or no interference.

2.2.7 Global Positioning System (GPS)

A GPS receiver was installed in the AVCS to provide an accurate time reference for data recorded in the GCS and the CCA Laptop.

2.3 Data Collection

To facilitate a detailed analysis of system performance, sensor errors, transmission latencies, and other issues, data was recorded at numerous points in the architecture indicated by the circled letters shown in Figure 5. Each source was equipped with a Global Positioning System (GPS) receiver to provide a consistent Coordinated Universal Time (UTC) reference for all the recorded data. The parameters listed in this section are the primary data used to perform the analysis described later in this document. A complete listing of all parameters recorded at each location is included in Appendix A.

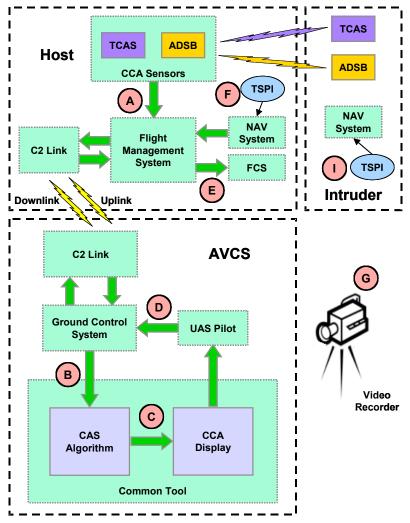


Figure 5. Data Collection Points for the CCA Technology Demonstration

2.3.1 Intruder (G-III)

The existing G-III instrumentation system was used to record multiple position sources and aircraft parameters. Data collection on the G-III intruder aircraft was limited to 'truth' position data and other aircraft performance parameters but did not include CCA sensor data since that data would also be available on the Host instrumentation. Pressure Altitude data was available from two of the position sources on the aircraft.

2.3.1.1 G-III 'Truth' Position Data Sources [Data Collection Point 'I']

There were five sources of time and space position information (TSPI) available on the G-III. As shown in Table 3, all five sources provided latitude and longitude information. The two FMS sources contained a blended solution using two inertial navigation systems, and they also provided pressure altitude data. The next two sources contained strictly GPS solutions. The fifth source contained a differential GPS solution expected to have better accuracy than the other data. All data was recorded at 40 Hz.

Data Source	Latitude/ Longitude	Pressure Altitude
Flight Management System 1 (fms1)	X	X
Flight Management System 2 (fms2)	X	X
Global Positioning System 1 (gps1)	X	
Global Positioning System 2 (gps2)	X	
ZXT GPS (zxt)	X	

Table 3. G-III 'Truth' Position Data Sources

2.3.2 Host (Proteus)

The Proteus had an existing instrumentation system that was used to collect and record aircraft data. However, the instrumentation system was modified to also record TCAS and ADS-B sensor data as it was prepared for transmission to the ground station. All data was recorded at 10 Hz. A complete parameter list is contained in Appendix A.

2.3.2.1 Proteus 'Truth' Position Data [Data Collection Point 'F']

There were two sources of TSPI available on the Proteus aircraft: GPS and Inertial Navigation System (INS). The INS values were a blended solution from a CMIGITS II GPS-aided inertial system. Although pressure altitude was not recorded directly on the aircraft, Static Pressure was recorded to allow calculation of the pressure altitude.

2.3.2.2 Proteus FMS Data [Data Collection Point 'E']

While the bulk of the parameters recorded on the aircraft were CCA sensor data, there were over 40 channels of aircraft state and system status data available to allow accurate determination of aircraft position and velocities in the three axes. Additional information from the autopilot provided indications when the ground pilot had control of the aircraft and when the aircraft received command inputs.

2.3.2.3 Proteus CCA Sensor Data [Data Collection Point 'A']

2 3 2 3 1 ADS-B Sensor Data

The FMS recorded 29 channels of ADS-B data that included information on the host aircraft and up to three intruders, as shown in Table 4. During the test planning process, the decision was made to limit the intruder data to three sets in order to control the amount of data transmitted due to bandwidth concerns. The 'number of intruders' parameter listed below is not an ADS-B parameter but was generated by the host aircraft. Because of limited usage of ADS-B near the test area, it was also anticipated that there would be no more than three ADS-B signals received from other aircraft at any time in the test. ADS-B data was updated at 1 Hz.

Table 4. ADS-B Parameters

Aircraft	Parameter	Description	
Host	ADSB_INT	Number of intruders	
	ADSBPRTS	Host vehicle ID	
Intruders	ADSBIntX	Intruder vehicle ID	
Host and Intruders	ADSBTmeX	ADS-B time stamp	
	ADSBLatX	Latitude	
	ADSBLngX	Longitude	
	ADSBAltX	Altitude	
	ADSBVVIX	Vertical velocity	
	ADSBLMRX	Data message missed	
X – (P) for Host, (1-3) for Intruders, e.g., ADSBLat2 is Latitude of Intruder #2			

2.3.2.3.2 TCAS Sensor Data

The FMS also recorded 30 channels of TCAS data for the host aircraft and up to three intruders, as shown in Table 5. As with ADS-B, intruders were limited to three even though TCAS is widely used and it was anticipated that more than three TCAS signals could be received at any given time. Also, as with ADS-B, the host aircraft generates the number of intruders parameter listed below. For TCAS, the Proteus FMS included logic to select the three closest aircraft for inclusion in the transmitted data. TCAS data was updated at 1 Hz.

Table 5. TCAS Parameters

Aircraft	Parameter	Description
Host	TCAS_INT	Number of intruders
	RA_Climb	Host TCAS Vertical RA Data
	RA_Dscnd	Output Word values
	RA_AltRt	
	RA_VrtCt	
	RA_CmbCt	
Intruders	TCASIntX	Intruder ID (set on Host)
	TCASTmeX	TCAS time stamp
	TCAS RngX	Relative range
	TCASBrgX	Relative bearing
	TCASRAIX	Relative altitude
	TCASArrX	Display arrow
	TCASACdX	Advisory code
	TCASSSMX	Data status
X - (1-3) for Intrude	ers	

2.3.2.4 Proteus Raw GPS

After initial review of the GPS data in the Proteus FMS data release, it appeared that the data had been corrupted in some way and did not provide accurate position information. Scaled

Composites was able to go back through the FMS flight data and prepare a release of the raw GPS data input to the FMS. This source was then added as a potential source for 'truth' position data.

2.3.3 Air Vehicle Control Station (AVCS)

2.3.3.1 Ground Control System (GCS) [Data Collection Points 'B' and 'D']

The GCS recorded the same CCA sensor data parameters sent by the aircraft plus the pilot control inputs sent back to the aircraft with a GPS time stamp from the receiver installed in the AVCS. This data was necessary to meet FSTO-2 and FSTO-5 goals for assessing the link delays and data missed rates.

2.3.3.2 Common Tool (CT) [Data Collection Point 'C']

In addition to recording the same CCA sensor data sent by the aircraft, the CT also recorded output from the ground collision avoidance logic to determine what was displayed to the pilot during each test run. The parameters unique to the CT are presented in Table 6. The CT recorded data at 10 Hz.

Parameter	Description		
AaAllClear	CT aural alert Boolean values		
AaDescend			
AaClimb			
AaVerticalSpeed			
RaVerticalControl	CT parameters controlling RAs		
RaClimb			
RaDescend			
RaAltRateGoal	RA vertical velocity goal		
Intr1AdvisoryCode	Advisory code for intruders		
Intr2AdvisoryCode	(Proximate, TA, RA)		
Intr3AdvisoryCode			

Table 6. Common Tool Display Parameters

2.3.4 Video Recorder [Data Collection Point 'G']

A video recorder was positioned to record the GCS and CT displays. For most of the flights, the recorder was turned on at the beginning of a test run, but there is no time reference or indication of the run number on the video. The video data was not used during the analysis described later in this report.

2.3.5 Scribe Notes

A test observer collected data recording the time of CCA aural and visual displays as well as when the ground pilot sent a command to the aircraft following an RA. The scribe used local time in the notes. The terms "yellow warning" and "red warning" refer to states of the CCA display in which the host aircraft symbol turns yellow to indicate a possible traffic conflict (TA) and red to indicate that an avoidance maneuver should be executed (RA). The term "all clear" refers to a state of the CCA display in which an aural announcement is made when the host is clear of a previous traffic conflict. The terms "climb climb", "descend descend", and "monitor

vertical speed" maneuver advis	refer ory.	to aural	warnings	made	by	the	CCA	display	to	coincide	with	a v	risual

3 Simulation Architecture

Three tools have been developed to simulate encounters requiring collision avoidance activities. The first, the CCA Performance Simulation, is a virtual software-only environment. The Systems Integration Lab, or SIL, includes several components of flight-quality collision avoidance hardware. The third tool, the Common Tool (CT), provides several functions, including a simple simulation of the ownships and intruders. The architectures of these tools are described in the following sub-sections.

3.1 CCA Performance Simulation

The CCA Performance Simulation is a Simulink®-based software application that can be used to analyze UAS collision avoidance in various encounter scenarios. A high level view of the simulation architecture is shown in Figure 6. Each of the air vehicles is represented by an element of code, which can be customized to model the desired closed-loop flight dynamics and CCA sensor equipage. The ownship segment also includes coded representations of the Air Vehicle Control Station and the CCA Laptop.

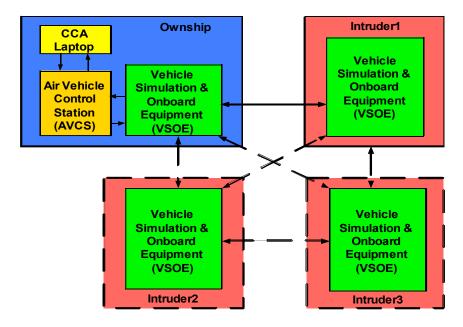


Figure 6. CCA Performance Simulation High-Level Architecture

The aircraft models can be initialized in a trimmed state for straight and level flight prior to running the model dynamically with time. By default, the aircraft fly following script-generated waypoints. However, pilot commands from the AVCS to the UAS can override waypoint following, thus allowing the UAS to avoid a potential collision. During these collision scenarios, the intruder aircraft continue to follow their previously computed waypoints.

The reason for developing the performance simulation is to have the capability to vary the multitude of parameters that describe an encounter scenario and then analyze the results. This

analysis will then be used to validate the collision avoidance functional requirements and perform safety analysis tasks as well. With so much depending upon the accuracy of the simulation output, it is essential that it be carefully tuned to match reality. This explains the motivation for performing the technology demonstration: providing real world data with which to validate the simulation. This ensures that the CCA Performance Simulation will then produce realistic data for further analysis and requirements validation.

3.1.1 Architecture

The CCA Performance Simulation is a four-vehicle simulation laid out in the architecture shown in Figure 6, of which an example is shown in Figure 7. Up to four vehicles (in any combination of UAS or manned), can coexist in the same airspace and transmit their own position information to the other aircraft via cooperative CCA sensors.

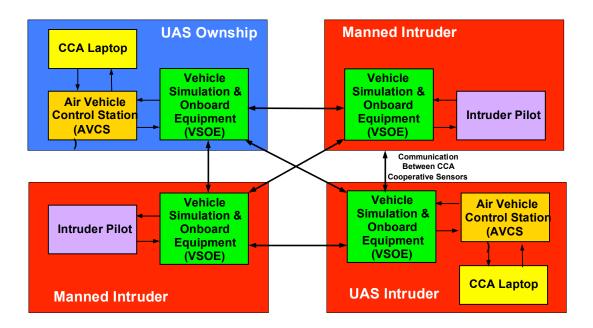
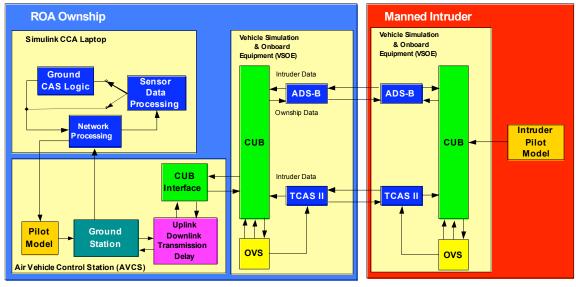


Figure 7. High-Level Simulation Architecture Example

Figure 8 provides more detail on the composition of the UAS Ownship model and a manned intruder model. The Vehicle Simulation and Onboard Equipment (VSOE) models for each type of aircraft are the same and include:

- An Ownship Vehicle Simulation (OVS) representing closed-loop flight dynamics of the air vehicle
- ADS-B and TCAS-II CCA sensor models
- A CCA Universal Box (CUB) element that represents translation of data between hardware elements.

The only differences between the manned vehicle model and UAS vehicle model are the inclusion of AVCS and CCA Laptop models and the location of the pilot model.



CUB = CCA Universal Box

CAS = Collision Avoidance System

OVS = Ownship Vehicle Simulation

Figure 8. UAS and Manned Aircraft Model Architectures

To date, the CCA simulation studies have been limited to two-vehicle encounter scenarios. Translation of the Figure 6 high-level architecture into its two-vehicle Simulink® equivalent is depicted in Figure 9.

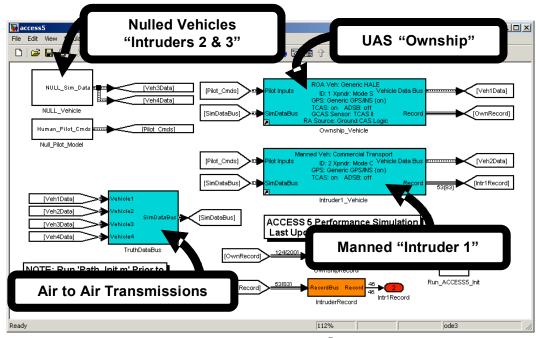


Figure 9. Simulation Simulink® Architecture

Here in the Simulink[®] simulation, each aircraft model is contained in its own block. Air-to-air communications have been consolidated into one massive signal, which is distributed to each aircraft. Since the simulation is set up for four aircraft, but only two vehicles are truly present, two empty or *nulled* vehicles exist to maintain internal signal dimensions.

The translation of the UAS and manned aircraft architectures from Figure 8 is shown in Figure 10 and Figure 11, respectively. Note again that each aircraft type shares common blocks like the TCAS-II and ADS-B. The only major difference is that the UAS aircraft model carries AVCS and CCA Laptop models.

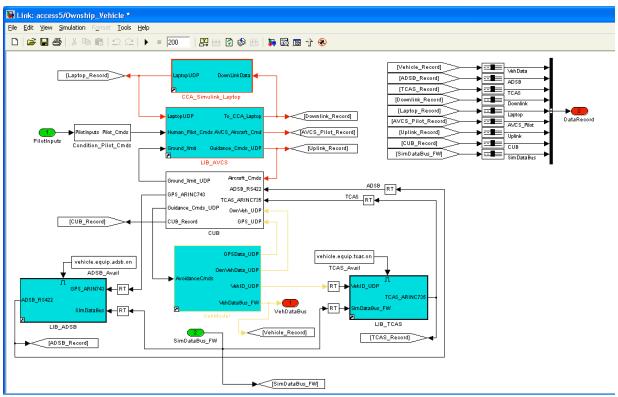


Figure 10. UAS Simulink® Architecture

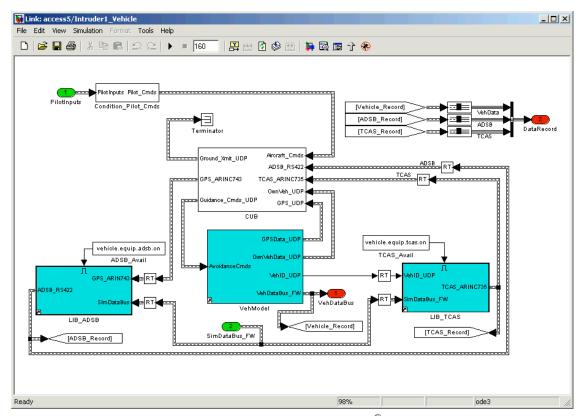


Figure 11. Manned Aircraft Simulink® Architecture

3.1.2 System Requirements

The CCA Performance Simulation was developed in MATLAB®/Simulink® for Windows/PC use. Models and code were developed on IBM NetVista machines using the programs listed in Table 7. The models are not backwards compatible with previous versions MATLAB® and Simulink®. The models must be used with the indicated version listed in the table below.

Name	Version	Operating System		
MATLAB®	7.0.4 (R14 SP 2)	Windows 2000 Pro, Windows XP		
Simulink®	6.2 (R14 SP 2)	Windows 2000 Pro, Windows XP		
Simulink [®] Stateflow	6.2 (R14 SP 2)	Windows 2000 Pro, Windows XP		
Microsoft .NET Framework 1.0	1.0.3705	Windows 2000 Pro, Windows XP		

Table 7. Software Development Toolset

A Linux version of the CCA Performance Simulation also has been developed but has not been fully tested.

3.1.3 Software Release

The CCA Performance Simulation version 2.0 was released on 13 February 2006 as deliverable CCA008-Rev2. The deliverable includes all the files needed to set up and run the simulation and

to simulate the Technology Demonstration flight runs. It also includes documentation such as a user's manual, a simulation Interface Control Document (ICD), and training materials.

3.2 CCA Systems Integration Lab (SIL)

The CCA SIL comprises a real-time, hardware-in-the-loop simulation residing at the Northrop Grumman Corporation in El Segundo, CA (Figure 12). Its purposes are to support the technology demonstration, to support simulation model validation, and to provide a test bed for continued analysis. It supported preparation for the technology demonstration by identifying the various issues that might arise when integrating the various pieces of hardware such as TCAS-II, ADS-B, and the Mode S transponder. It proved valuable during the technology demonstration to troubleshoot data link and intruder tracking issues and to develop and test revised CAS logic to accommodate the flight test setup. It also serves as a platform for testing the Common Tool and its interfaces to the system. Because it contains real hardware, the SIL is also able to validate the simulation component models for TCAS and ADS-B. Finally, the SIL provides a test bed for continued analysis of collision avoidance requirements. Once it is validated, the SIL can be used to assess an expanded set of encounter scenarios beyond the limitations of the CCA technology demonstration.

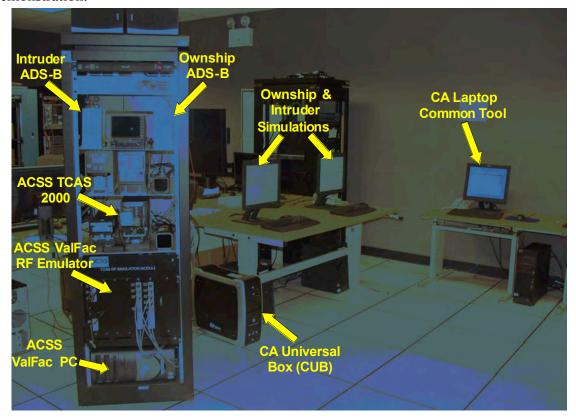


Figure 12. CCA Systems Integration Laboratory (SIL)

3.2.1 Architecture

The CCA SIL architecture is shown in Figure 13. Items in red represent actual flight hardware, while the yellow boxes each represent a computer. The simulation data bus, shown in green, passes data between simulation elements. The various busses connecting the hardware elements

are color coded as shown in the key. Each major element of the SIL is described in more detail below.

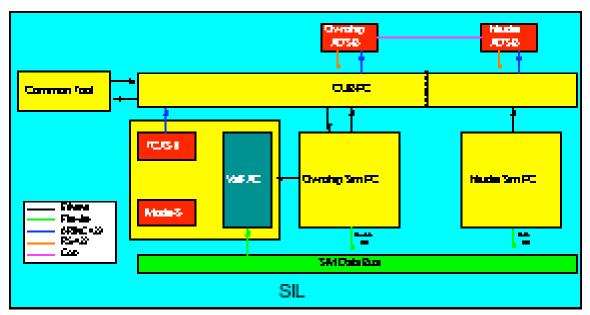


Figure 13. CCA SIL Architecture

The TCAS II, Mode-S and ValFAC work together to provide the TCAS CCA sensor function. The TCAS II hardware is the same ACSS TCAS 2000 suite installed in the Proteus and described in Section 2.1.1.1.1. The processor is the ACSS RT-951 receiver/transmitter, and the Mode S transponder is the ACSS RCZ-852. The ValFAC (Validation Facility), shown in Figure 14, is a piece of laboratory hardware procured from ACSS that allows end to end use of the TCAS system in a laboratory environment. The ValFAC is driven by simulation data and outputs an RF environment to the TCAS antenna ports. The TCAS II unit passes data to the rest of the SIL over the ARINC 429/735 display data bus via the CUB.



Figure 14. ValFAC

The SIL contains two ADS-B units: one each for the ownship and the intruder. The ADS-B equipment, shown in Figure 15, is the same Garmin GDL 90 model installed in the Proteus and described in Section 2.1.1.1.2. The ADS-B units communicate with each other in the SIL over RF via line leakage from terminated coaxial cables attached to each unit's antenna port. Each units GPS positions is driven by simulation data supplied by the CUB over ARINC 429/743A. They pass data to the rest of the SIL over the RS-422 port, configured to output traffic data, via the CUB.



Figure 15. ADS-B Unit

The ownship and intruder simulation PCs use the Linux operating system to run a real-time version of the CCA Performance Simulation's OVS. The individual vehicle simulations are prepared by generating C++ code from the Simulink® OVS block subsystem. Simulink® outputs an initialization data file containing vehicle parameters, trim states, and mission plan. The scenario can be modified without recompiling. The ownship simulation PC also drives the heartbeat of the entire SIL simulation.

The CCA Universal Box (CUB) was designed as a universal converter between different hardware and software interfaces. Hardware interfaces involved in the ACCESS 5 SIL includes Ethernet, ARINC 429, and RS422. These interfaces require special communication hardware and software, therefore, a custom built PC loaded with SUSE Linux and a software package was developed to synchronize, convert, and transfer data flowing through the simulation. Figure 16 shows both a diagram of the translations performed by the CUB and a photo of the real hardware with connectors. The CUB provides some of the functionality of both the onboard and GCS processing. Interfaces include:

Ethernet: Ethernet is used to provide point to point communication for Non-Time Critical Data. Because of its well defined interface structures and ease of use, it is being used as an interface for CCA Laptop to Ground Control Station

RS-422: RS-422 is used for receiving Traffic Data from GDL-90 Traffic Data Bus

ARINC 429: An ARINC 429 card is used for both transmitting GPS Input to GDL-90 using ARINC 743A label format and receiving TCAS-II Traffic Data using ARINC 735 label format.

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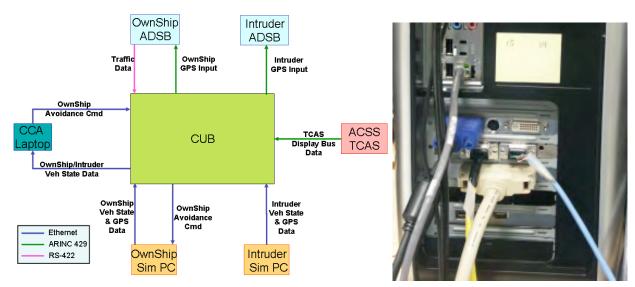


Figure 16. CCA Universal Bus (CUB)

The Common Tool provides CCA display and pilot input functions. A picture of both these functions is shown in Figure 17.

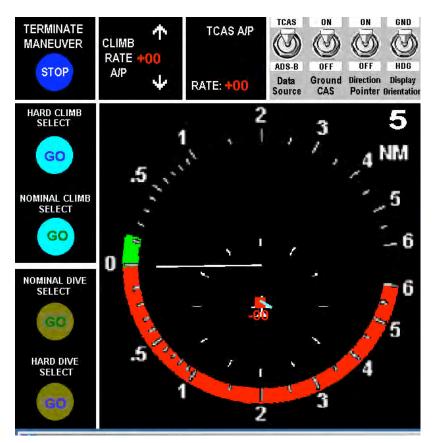


Figure 17. Common Tool Display in SIL

3.2.2 Software

The SIL consists of many software elements. Table 8 lists the versions of all of the software modules used. The vehicle model is auto-coded from the Vehicle_Model subsystem of the SIL_SIMULATION_V2_0 and is built from the same library block as the performance simulation. To match the flight test, software version 4p4 of the common tool and version 4p0/4p1 of the ground CAS is set up for use in the SIL.

	•
Software Element	Version
Vehicle Mode	SIL_SIMULATION_V2_0
Common Tool	Version 4p4
Ground CAS	NGC_CAS_v4_0
	NGC CAS v4 1

Table 8. SIL Software Configuration

3.3 Common Tool

Among its many functions, the CT can provide a simple simulation of the ownship and intruders. The CT also serves as the CCA Laptop in the SIL, providing CCA display and pilot input functions. Figure 18 outlines the functional architecture of the CT and its available hardware interfaces.

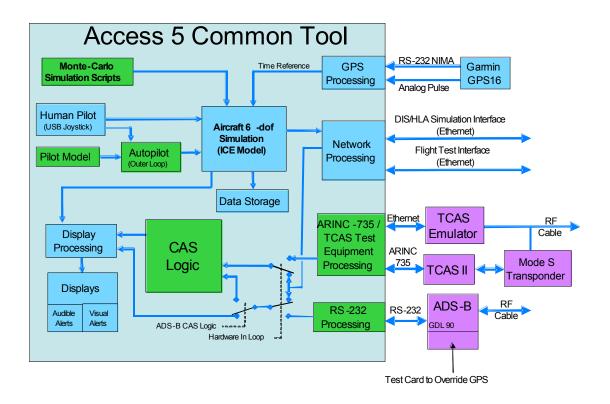


Figure 18. Common Tool Architecture

4 Test Conduct

The flight demonstration was conducted in the Isabella Military Operating Area (MOA) near Edwards AFB, CA, between 21 September 2005 and 28 September 2005. During the program six flights were flown, with Proteus (21.5 flight hours) as the Host aircraft and the G-III (19.8 hours) serving as the Intruder. Flights were executed in accordance with the NASA Access 5 Cooperative Collision Avoidance Step 1 Technology Demonstration Flight Test Plan, Revision 1.5, dated 12 August 2005. Table 9 shows a summary of the flights.

Access 5 Flt No.	Date	Proteus Flt No.	G-III Flt No.	Runs	Common Tool Data (Runs)	Comments				
A5-1	21 Sep 05	368	23	16	16	No time stamp on Proteus data				
A5-2	22 Sep 05	369	24	15	13					
A5-3	22 Sep 05	370	25	12	11					
A5-4	23 Sep 05	371	26	0	None	Photo Chase				
A5-5	26 Sep 05	374	27	4	4					
A5-6	27 Sep 05	375	28	27	27	Proteus FMS data delivered for first 23 runs only				

Table 9. CCA Technology Demonstration Flights Summary

4.1 Test Runs

While the focus of Access 5 Step 1 is operation above FL 430, the demonstration was conducted at 15,000 ft MSL for test efficiency and to provide a sufficient flight envelope margin for the aircraft to perform avoidance maneuvers when required. For a test run, each aircraft departed from an Initial Point (IP) at a time that would have them arrive at the intercept point simultaneously. The Proteus aircraft always used the same IP while the G-III used four different IPs to generate co-heading, low-aspect, abeam, and head-on encounter geometries. For level (constant altitude) runs, the aircraft departed their IPs at the planned safety buffer separation altitude of 300 ft with the G-III always below the Host. For runs requiring either of the aircraft to be changing altitude during the encounter, the aircraft departed with an increased altitude separation, and the desired climb/descent rate was established at a time that would result in the required minimum 300 ft altitude separation at the point of closest approach.

4.1.1 Airspeed

The Proteus test airspeed, 110 KIAS, was in the heart of Proteus's speed envelope at 15,000 ft MSL. The G-III speed, 300 KIAS, was selected to provide typical closure rates between HALE aircraft and airliner traffic at FL 430 while remaining within the G-III operating speed envelope.

4 1 2 Test Matrix

Each test run was defined by a combination of an encounter geometry scenario, a CCA sensor/maneuver advisory suite, a look-ahead buffer, a data link latency, and a climb performance limit. The resulting combinations that were selected for demonstration are summarized in Table 10, while an explanation of each element is provided in the following subsections. The total number of planned test runs resulting from this matrix was 54.

Table 10. Test Run Matrix

Scenario	Sensor / Maneuver Advisory Suite ¹	Look-Ahead Buffer (sec)	Link Delay (sec)	GCAS Max Climb Rate (fpm)	TCAS Climb Inhibit			
1,2,3	TGC	0	0	1000	n/a			
	AGA	0	0	1000	n/a			
	TRT	0	0	n/a	Yes			
	TRT	0	0	n/a	Yes			
4,5,6	TGC	6	0	2500	n/a			
	TGC	4	0	2500	n/a			
	TGC	2	0	2500	n/a			
	TGC *	0	0	2500	n/a			
	TGC	4	2	2500	n/a			
	AGA	6	0	2500	n/a			
	AGA	4	0	2500	n/a			
	AGA	2	0	2500	n/a			
	AGA *	0	0	2500	n/a			
	AGA	4	2	2500	n/a			
	TRT	0	0	n/a	No			
	TRT	0	0	n/a	No			
One repetition for each configuration except two for those marked with *								

4.1.2.1 Encounter Geometry Scenario

Each flight consisted of a series of encounters between the two aircraft using the scenarios shown in Figure 19. These scenarios are a subset of geometries previously used for TCAS analysis that were selected on the basis of anticipated real-world encounters between a UAS at or above FL 430 and a faster moving intruder aircraft. Additionally, the selection process attempted to provide a variety of encounters that would facilitate validation of the simulation. Finally, safety of flight tailored the encounters to maximize safety pilot visibility from the intruder aircraft.

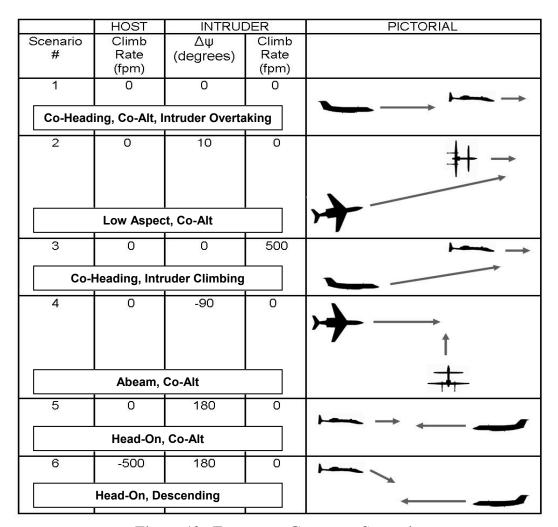


Figure 19. Encounter Geometry Scenarios

4.1.2.2 Sensor/Maneuver Advisory Suite

The test architecture was designed to test three CCA sensor/maneuver advisory suite configurations that examined the tradeoffs between the two sensor technologies and the source of the collision avoidance logic. The three-letter nomenclature used in Table 10 to specify the sensor suite consists of:

First letter: the host aircraft sensor (A - ADS-B or T - TCAS),

Second letter: the logic used for generating alerts (G – Ground CAS logic or R – On-board TCAS logic), and

Third letter: the intruder aircraft sensor (A – ADS-B, C – Mode C Transponder or T – TCAS).

The specific combinations used in the technology demonstration are translated in Table 11 and described in the following sub-sections.

Table 11. Sensor/Maneuver Advisory Suite Nomenclature

Acronym	Host Aircraft CCA	Maneuver Advisory	Intruder Aircraft
	Sensor	Source	CCA Sensor
TGC	TCAS II	Ground CAS Logic	Mode C Transponder
AGA	ADS-B	Ground CAS Logic	ADS-B
TRT	TCAS-II	On-board TCAS	TCAS-II/Mode S
		Resolution Advisory	

4.1.2.2.1 TRT

The host TCAS system receives information from the intruder transponder, and the on-board TCAS collision avoidance logic calculates range, bearing, and relative altitude information. The Host TCAS system issues Traffic Advisories (TA) when required and coordinates Resolution Advisories (RA) with the intruder to ensure the aircraft execute compatible maneuvers (although only the host executes the avoidance maneuver). The information is passed through the aircraft FMS to the AVCS for display on the Common Tool.

4.1.2.2.2 TGC

The Host TCAS system receives the Intruder Mode C transponder information and passes range, bearing and relative altitude to the Ground Collision Avoidance System (CAS) logic through the aircraft FMS and GCS. The ground CAS logic uses algorithms similar to TCAS to issue advisories that are displayed on the Common Tool display. In this case, however, the RA cannot be coordinated with the intruder and only the host executes a maneuver when required.

4.1.2.2.3 AGA

This sensor suite is similar to TGC except the position data is supplied by the host and intruder ADS-B systems. The host receives a position broadcast from the intruder that contains latitude, longitude, and altitude information. That data, and the host position data, is transmitted to the ground CAS logic through the same communication links as in the other suites. The CAS logic then converts the latitude and longitude data for both aircraft into relative range and bearing that are used to issue TAs and RAs exactly as in the TGC configuration

4.1.2.3 Look-Ahead Buffer

This time represents an additional "look-ahead" that was used in the ground CAS logic to issue RAs before the time a TCAS RA would have been issued. It was implemented to examine options to offset data latencies and to provide an additional safety buffer during the flight test. It was varied from 0 to 6 seconds in 2 second increments during abeam and head-on scenarios because of higher closure rates.

4.1.2.4 Link Delay

The latency generator in the GCS provided the option to delay transmission of data to and from the aircraft. It was used during the flight demonstration to examine the effects of beyond line-of-sight communication delays. For the abeam and head-on scenarios, runs were made with no buffer/no link delay and then with 4 sec buffer/2 sec link delay to determine if similar results were obtained.

4 1 2 5 Climb Performance

The climb capability of UAS can vary greatly at FL 430. To demonstrate the CCA architecture in both a higher performance UAS and in those that are approaching their service ceiling, settings were used in both the ground CAS logic and in the TCAS to limit climb performance for the co-heading and low-aspect runs. These scenarios were selected to demonstrate reduced UAS performance because they presented a lower flight test risk with slower closing velocities and clear visibility of the host from the intruder.

4.1.2.5.1 GCAS Maximum Climb Rate

The ground CAS logic had a software setting that was used to limit the maximum rate of climb commanded during an RA. For the co-heading and low-aspect scenarios, the climb rate was limited to 1000 fpm while a rate more consistent with TCAS, 2500 fpm, was used for the remaining scenarios.

4.1.2.5.2 TCAS Climb Inhibit

For the TRT runs at co-heading and low aspect, a limited climb capability was demonstrated by configuring the TCAS installation pin settings to indicate the aircraft had limited climb capability at that altitude and therefore inhibit a climb RA.

4.2 Test Summary

Seventy-two total data passes were accomplished during the six flights. Fifty-three of the 54 test points were attempted with 49 accomplished successfully. Additionally, six runs were accomplished twice – once each with different versions of the Common Tool and CAS algorithm. Forty-five of the 72 passes included an avoidance maneuver through the point of closest approach.

5 Data Processing

This section describes the data received from the technology demonstration, the method used to process the data, and rationale for selecting from redundant data.

5.1 Methodology

Data from the various recording points (Section 2.3) was provided to the CCA Work Package team in large data files of various formats. Scaled Composites provided Proteus aircraft and GCS data as ASCII text files identified by flight number. They ranged in file size from about 110 MB to over 300 MB. The G-III data for each flight contained a separate 7-24 MB file for each of the 73 parameters recorded. These sources recorded data for the entire flight without an indication of the beginning or end of the individual test runs. The Common Tool data, however, was recorded for each run in a 3-25 MB file depending on the length of the run. Additionally, raw Proteus GPS input data files of 1-4 MB were provided after preliminary analysis identified corrupt GPS position data recorded in the FMS. All raw data was processed with Visual Basic 6 applications developed by the CCA Work Package, and selected parameters were loaded into Microsoft Access databases to facilitate analysis. All data files except the raw GPS contained a GPS Coordinated Universal Time (UTC) time stamp.

The first step in loading the data was to identify start and stop times for each of the runs. The FMS data contained a parameter that indicated when the autopilot was engaged and disengaged. This indicated when the ground pilot took control at the beginning of the run and when the pass (encounter) was terminated. Using the times for these two events, the data was loaded and indexed to flight and run number for all the data sources.

In order to compare data between the various sources, a common time step reference was required. The G-III data was recorded at 40 Hz and other sources were recorded at 10 Hz. Most of the data to be analyzed, GPS, ADS-B, and TCAS, only updated at 1 Hz. Figure 20 shows how the first time step for each data update was selected and then data points were interpolated to place the data points at common time points every half second at time fractions of .0 and .5 sec. Capturing interpolated data at 2 Hz was determined to be sufficient to represent the 1 Hz data.

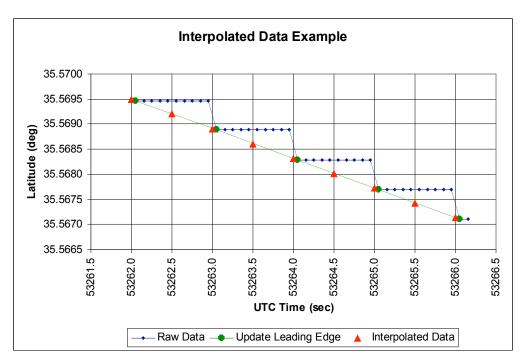


Figure 20. Interpolated Data Example

5.2 G-III Truth Data

Although several position sources were available on the G-III, as shown in Table 12 only one source was available for all of the 72 runs accomplished due to either missing or frozen data. GPS1 was selected as the 'truth' source to provide a consistent position reference for analysis even though the zxt source was expected to have more precise data. Data values were interpolated at half-second increments as described in Section 5.1.

Table 12. G-III Latitude/Longitude Position Source Availability

System	Availability
Flight Management System 1 (fms1)	8%
Flight Management System 2 (fms2)	5%
Global Positioning System 1 (gps1)	100%
Global Positioning System 2 (gps2)	72%
ZXT GPS (zxt)	50%

5.3 Proteus Truth Data

After initial plots of the Proteus GPS, INS, and ADS-B data indicated that the GPS data had been corrupted by FMS processing, the INS reference remained the only available option for 'truth' data since ADS-B was to be compared to the truth in the analysis. Since ADS-B is a pure GPS solution, it was preferable to compare that data to another GPS source instead of a blended GPS-INS solution, and a request for corrected GPS data was sent to Scaled Composites. Even though the data couldn't be corrected in the FMS, the raw GPS inputs were available and were processed for use as the 'truth' source. The raw GPS data was referenced to midnight on Sunday

with a 13 second leap-second correction required to reference the data to UTC. Data values were interpolated at half-second increments as described in Section 5.1.

5.4 ADS-B Sensor Data

The ADS-B data necessary for position error determination was recorded by the FMS. Both host and intruder latitude and longitude information was interpolated in the same manner as the 'truth' data. All ADS-B parameters updated simultaneously, so the interpolation was accomplished by looking for changes in the latitude data only.

5.5 TCAS Sensor Data

The TCAS data necessary for position error determination was also recorded by the FMS. This data, expressed in terms of relative range, bearing, and altitude, was processed using the same interpolation methodology used for the 'truth' data. All TCAS parameters updated simultaneously, so the interpolation was accomplished by looking for changes in the range data only.

5.6 GCS Data

The GPS time reference recorded for this data did not use the full GPS timing information, and it was recorded as integer seconds only. Since multiple records with the same integer time stamp were recorded, it was impossible to reconcile the data to whole and half seconds. All parameters recorded by the GCS were extracted from the text files and stored in a MS Access database, but the data was not used for further analysis.

5.7 Common Tool Data

Each CT data file consisted of the data for a particular run during a flight. The naming convention for the files made it easy to correlate them with the run data recorded by the FMS. This data provided the only source of data relating to the aural and visual displays presented to the pilot. All parameters in this data were extracted from the text files and stored in a MS Access database, but interpolated data was not generated. Leading edge data was identified for use in latency and missed message performance since the GCS data was not suitable.

6 Analysis and Results

6.1 Scope of Analysis

Analysis of the flight test data was focused on determining values for the metrics listed for the test objectives in **Table 13**. These would then be used to validate the CCA Performance Simulation and SIL.

Table 13. Scope of Analysis

Objective	Description	Metric
FSTO-1	Collect data to validate CA sensor models.	Range Error
		Azimuth Error
FSTO-2	Collect data to validate link affect models on the	Intruder – Host Latency
	transmission of CA sensor data.	Host – GCS Latency
		(downlink)
FSTO-3	Collect data to validate the CA display.	
FSTO-4	Collect data to validate operator response to the CA	Pilot Reaction Time
	display.	Pilot Response
FSTO-5	Collect data to validate link affect models on the	GCS- Host Latency
	transmission of operator evasion commands to the	(uplink)
	vehicle.	
FSTO-6	Validate the vehicle model during an evasion	
	maneuver.	
FSTO-7	Collect data to validate the resulting miss distance	Point of Closest Approach
	between the UAS and intruder during a collision	
	avoidance scenario.	

For sensor position error calculations (FSTO-1), the Data Analysis Plan (DAP) called for collection of truth position data for both aircraft to be used to calculate the actual range and bearing between the aircraft for comparison with the values resulting from the sensors. The UTC times at which the sensor updates were recorded on the intruder, host, GCS, and CT were planned to provide a complete timeline for determining the delay between the intruder sensor and ground pilot display (FSTO-2).

For determining the pilot reaction time element of the timeline (FSTO-4), the DAP called for collecting the time an RA was displayed to the pilot on the CT and the time that a command input was received at the GCS. The pilot response parameter (FSTO-4) compared the CT climb/descend rate recommended by the RA with the command input entered by the ground pilot to determine if pilot responded properly.

Determination of the final element of the RA timeline, transmission latency of the command to the aircraft (FSTO-5), required the time the command was input at the GCS and the UTC time in the FMS that the command was received on the aircraft. Analysis of the Miss Distance (FSTO-7) relied on collection of truth position data for the intruder and host to calculate the point of closest approach. Analysis to support FSTO-6 was the responsibility of the Flight IPT, and the results of that effort are included in the technical report to be released by the Flight IPT.

6.1.1 Run Selection

Runs were selected for analysis by developing two sets of charts, examples of which are shown in Figure 21 and Figure 22. The first set of four charts depicts Proteus and G-III truth data for latitude, longitude, pressure altitude, and range between aircraft. These charts were reviewed to find runs with a relatively consistent rate of change in latitude and longitude indicating limited maneuvering during the encounter run-in because simulation of these runs would be easier to model. To simplify modeling, it was also necessary to select runs with limited changes in altitude before a RA since the algorithms are dependent on the relative altitude of the intruder. Additionally, selection was based on runs with TA and RA events that could be replicated in the simulation.

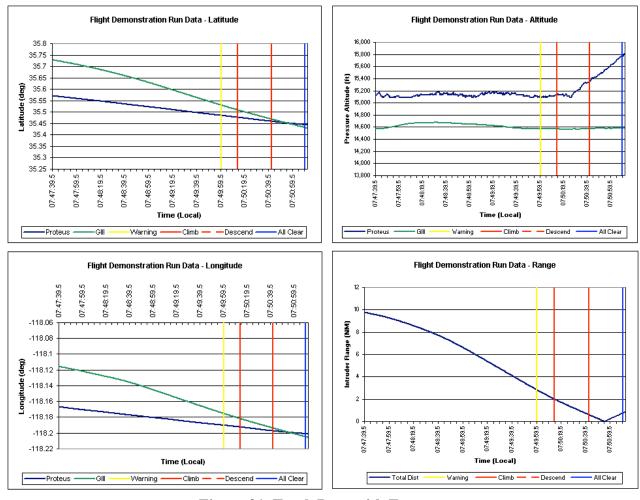


Figure 21. Truth Data with Events

The TCAS Track plots were used when selecting TGC runs for analysis. During planning for the flight test, link bandwidth concerns led to the decision to limit intruder tracks recorded by the FMS and passed to the GCS to three for both ADS-B and TCAS. Implementation of the selection logic in the Proteus FMS resulted in the possibility that the G-III data could change tracks during a run or even not be included in the three tracks selected by the FMS. A process was developed during analysis to determine which of the three tracks, if any, was the G-III.

Figure 22 is an example of a run where the G-III remained in the Intruder 1 track (Blue) and the logic correctly identified that track as the G-III (Red). Appendix D contains the track plots for all TGC runs during flight A5-6.

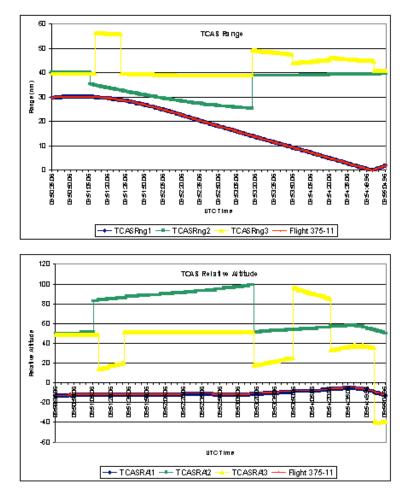


Figure 22. TCAS Track Determination

6.1.2 Limitations

A complete analysis of the flight test data was not accomplished due in part to the late delivery of the Proteus and GCS data by Scaled Composites. Another factor was additional post-processing requirements that were not originally anticipated in the analysis plan. Finally, the premature termination of the Access 5 program led to an abbreviated analysis of the technology demonstration data. This report identifies recommended areas for follow-on work in the conclusions section. Specific issues discovered during data processing and analysis that limit the usefulness of the data are detailed in the following sub-sections.

6.1.2.1 Data Timing

During test planning, the Flight IPT and the CCA Work Package made the decision to use GPS-provided latitude, longitude, and UTC time as 'truth' data for both aircraft. It was assumed that using a common position source and timing would permit an accurate calculation of relative

position during the runs. During analysis of ADS-B data range errors, a problem with the timing became evident during latency calculations.

When the comparison was made between the intruder and host times, results showed cases where ADS-B position updates were recorded at the host prior to the intruder instrumentation system recording that position for the GPS 'truth' data. Realizing that the recorded times for each aircraft were instrumentation times and may not reflect the sensor time, it was unclear if there was a timing difference between the aircraft or if the instrumentation process on the intruder aircraft induced delays in recording the data. Without a method to isolate the timing errors from the total error, the position errors and latency times could not be accurately determined.

6.1.2.2 FTSO-3

Although the CCA Work Package developed a Pilot Questionnaire for the ground pilot to complete after each run, no specific parameters were developed to validate the CA display. Since the flight test used a test-expedient pilot display that was not intended to represent an operational system, validation of the display was not attempted during flight test. Data was collected only to potentially identify runs where the pilot had a problem interpreting the display so reaction time might not be representative.

6.1.2.3 GCS Timing Reference

The GCS timing reference did not include the fractional part of the GPS timing signal and was quantized in integer seconds only. Latency calculations between the aircraft and the ground station were approximated the FMS and Common Tool data where accurate timing was available.

6.1.2.4 GCS Pilot Command Input

The GCS data inadvertently omitted the autopilot parameter that recorded the climb/descent rate command entered by the pilot and sent to the aircraft in response to an RA. Pilot reaction time could only be estimated by using the time between the CT display of an RA and when the rate command was received by the aircraft FMS and subtracting the downlink time which was assumed to be the same as the uplink time.

6.2 ADS-B Sensor Characterization

Prior to data analysis, a set of performance metrics was identified to model the ADS-B system in the CCA Performance Simulation. Table 14 lists the metrics and results that were used to set Performance Simulation variables characterizing the system. The data analysis methodology and resulting value for each metric are described below.

The flights selected for analysis of data transmission from the aircraft to the ground station were A5-5 and A5-6. Telemetry (TM) problems identified by the flight test team during earlier flights resulted in poor data transmission between the Proteus and ground station that caused unrealistically poor performance statistics. Improvements to the system before the selected flights resulted in a better performing TM system representing a reliable though not production-quality communication system. Flight test data for all runs used in this analysis was limited to the time period that the ground pilot had control of the aircraft.

For this demonstration, the G-III (intruder) aircraft was generally the only ADS-B equipped aircraft within reception range of the Proteus (host) system. When the G-III ADS-B system was detected, the data was collected in the FMS in the Intruder 1 data fields.

Table 14. ADS-B Performance Metrics

Metric	Result
Intruder-Host Missed Message Rate (%)	6.2%
Intruder-Host Message Latency (sec)	Undetermined
Range Error (ft)	Undetermined
Azimuth Error (deg)	Undetermined
Relative Altitude (ft)	Undetermined
FMS-CT Missed Message Rate (%)	18.67%
FMS-CT Transmission Latency (sec)	1.63

6.2.1 Intruder-Host Missed Message Rate

This metric measures the percentage of the ADS-B position updates in the Proteus GDL 90 ADS-B system that are based on extrapolated data because of a missed transmission from the intruder aircraft. When an ADS-B intruder message is missed during a time step, the GDL 90 sets a parameter to indicate the missing update.

Intruder ADS-B data recorded in the Proteus FMS at 10 Hz contains an integer-value time stamp (ADSBTme1) and Data Message Missed (ADSBLMR1) parameter to indicate if a new update was received from the intruder. Since the ADS-B update rate is 1 Hz, the data was limited to only the first record for each time step to analyze ADS-B performance and not overall transmission quality of the system.

The Missed Message parameter in the FMS data was evaluated to determine the percentage of those updates that were based on extrapolated data during the selected runs, thus determining the ratio of missed to total messages. Table 15 summarizes the missed message data.

Table 15. ADS-B Missed Message Data

Intruder-Host Missed Message Rate (%)		
Messages Received -Total	14,736	
Messages Received – No Update	914	
Missed Message Rate	6.2%	

6.2.2 Intruder-Host Message Latency

This value could not be determined because of a suspected timing difference in the G-III instrumentation system.

6.2.3 Range and Azimuth Error

The G-III 'truth' position at a specific time couldn't be compared to FMS data because of the data timing issue. Therefore, values for range and azimuth error could not be determined. The data was analyzed to determine position errors for each of the aircraft, Table 16. For the Proteus ADS-B versus GPS systems, the data was from the same FMS source, and the error is limited to GPS errors only. The results are well within expected GPS error bands. For the G-III, ADS-B position was taken from the Proteus FMS and the 'truth' position from the G-III instrumentation.

The error for the G-III reflects the addition of error due to timing differences to normal GPS position error.

Table 16. ADS-B Position Errors

ADS-B Position Errors (ft)		
Characteristic Proteus G-III		
Mean	26.62	334.74
Standard Deviation	16.01	79.32

6.2.4 FMS-CT Missed Message Rate

This metric measures the percentage of Proteus GDL 90 ADS-B position updates recorded by the aircraft FMS that were not received by the GCS. Only the leading edge of each ADS-B latitude update was analyzed for the flights following the improvement to the TM system. For each new host latitude value (ADSBLatP) recorded on the aircraft, CT data was searched to see if that value was recorded on the ground. If the value was not recorded, it was considered a missed message due to the C2 downlink resulting in the data in Table 17.

Table 17. ADS-B Downlink Missed Messages

FMS – CT Downlink Missed Message Rate (%)		
Messages Received -Total	7,273	
Messages Received – New Update	1,358	
Missed Message Rate	18.67%	

6.2.5 FMS-CT Message Latency

Prior to flight test, the DAP called for downlink latency to be measured by the delay between recording the data on the aircraft and in the GCS. Following receipt of the GCS data, it was determined the data did not have the fidelity required for this measurement. Therefore, the latency reported for the flight test is between the FMS and the CT and serves as an approximation of downlink delay. As the data was analyzed for missed data, the times for each matching pair of data between the FMS and CT were recorded and delay statistics were prepared, Table 18. As in the missed message analysis, only the ADS-B update data for the last two flights was used.

Table 18. ADS-B Downlink Transmission Latency

FMS-CT Transmission Latency (sec)		
Mean	1.63	
Standard Deviation	.45	

6.3 TCAS Sensor Characterization

Performance metrics used for TCAS varied slightly from the ADS-B characterization since TCAS calculates range, relative altitude, and bearing information on board the host and does not receive a position update from the intruder. Table 19 lists the metrics and results that were used to set CCA Performance Simulation variables characterizing the system.

Metric	Result	
TCAS Missed Update Rate (%)	Undetermined	
TCAS-FMS Latency (sec)	.20	
Range Error (ft)	Undetermined	
Azimuth Error (deg)	Undetermined	
Relative Altitude (nm)	Undetermined	
FMS-CT Missed Message Rate (%)	12.98%	
FMS-CT Transmission Latency (sec)	1.59	

Table 19. TCAS Performance Metrics

The analysis of data transmission from the aircraft to the ground station was restricted to the same flights as for ADS-B because the downlink delay was common to both systems. As described in Section 6.1.1, the G-III TCAS data was not consistently on a single track and may not have even been recorded during a run. The runs used in this analysis were limited not only to the last two flights, but also to the runs where the G-III track could be clearly identified throughout the run. The smaller sample size led to differences in the FMS to CT statistics between the two systems that were not considered statistically significant. Flight test data for all runs used in this analysis was limited to the time period that the Ground Pilot had control of the aircraft and CT data was being collected.

The TCAS analysis was performed in the same manner that the ADS-B data was analyzed, as described in the sub-sections below.

6.3.1 TCAS Missed Update Rate

An appropriate methodology was not developed to determine this metric as a part of the flight test analysis. An approach was examined to determine the duration that a range value was recorded in the FMS and assume that if the range did not change for more than the expected update rate, TCAS had missed data. With the instrumentation recording at 10 Hz and a TCAS 1 Hz track file update rate, it was anticipated that a new TCAS range would appear every ten records. The data did not follow this simplified expectation and it was unclear if this approach would lead to an accurate assessment of TCAS performance. With limited analysis time, the result was therefore undetermined.

6.3.2 TCAS-FMS Latency

This metric describes the time delay between the TCAS position update and the time that the data is recorded in the FMS at a 10 Hz data rate. The TCAS time (TCASTme) recorded for each of the updates to TCAS range, relative altitude and bearing was compared to the time stamp on that record (INS_Time) to determine the delay. Results are shown in Table 20.

Table 20. TCAS-FMS Latency

TCAS-FMS Latency (sec)		
Mean	.20	
Standard Deviation	.12	

6.3.3 Range, Relative Altitude and Azimuth Error

As with ADS-B, these metrics were undetermined because of the timing issue between the G-III and Proteus instrumentation systems.

6.3.4 FMS-CT Missed Message Rate

This metric measures the percentage of TCAS position updates recorded by the aircraft FMS that were not received by the GCS. Only the leading edge of each TCAS range update was analyzed for the flights following the improvement to the TM system. The FMS TCAS data was preprocessed for this analysis to determine which track represented the G-III, and only those runs where the G-III data was available for the entire run were used. The limited number of runs still resulted in values that met the expectation that the statistics for transmitting TCAS data to the ground would be similar to the statistics for ADS-B. If a range in the FMS was not recorded in the CT, it was considered a missed message due to the C2 downlink. Table 21 summarizes the missed message data.

Table 21. TCAS Downlink Missed Messages

FMS – CT Downlink Missed Message Rate (%)		
Track Updates Received -Total 940		
Track Update Missed	122	
Missed Message Rate	12.98%	

6.3.5 FMS-CT Message Latency

As with the ADS-B data, the DAP called for downlink latency to be measured by the delay between recording the data on the aircraft and in the GCS, but the GCS data timing fidelity required that the CT data be used instead. Table 22 reflects the delay between matching pairs of data in the FMS and CT. As in the ADS-B analysis, only the data update leading edge for the last two flights was used.

Table 22. TCAS Downlink Transmission Latency

FMS-CT Transmission Latency (sec)		
Mean	1.59	
Standard Deviation	.65	

6.4 Pilot Model

The pilot model consists of two metrics, reaction time and response accuracy. Due to UTC timing data fidelity in the GCS, the reaction time is calculated using RA display captured in the CT and receipt of the pilot command by the FMS.

6.4.1 Pilot Reaction Time

This delay is the sum of the actual pilot response time between observing an RA and inputting the command and the C2 uplink latency. A better estimate for the pilot reaction time can be made by assuming the uplink delay is the same as the downlink and subtracting that time from the total delay. The data in Figure 23 shows only runs where a pilot command was sent to the aircraft.

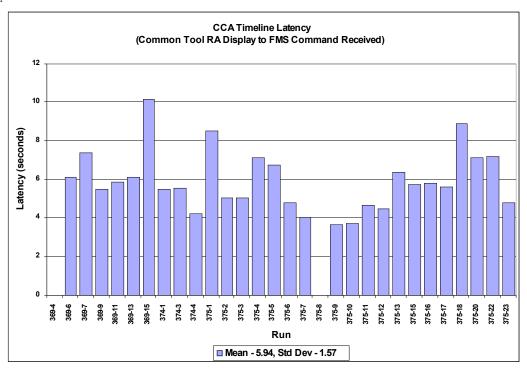


Figure 23. CCA Timeline Latency (Pilot Reaction + Uplink Latency)

6.4.2 Response Accuracy

During the flight test, the pilot had a set of discrete command inputs from which to select when an RA was displayed. An aural climb command was accompanied by a visual display on the Vertical Speed Indicator (VSI) that identified a range of vertical speeds. The pilot was given instructions to respond to an RA with a climb/descend value that fell within that range of vertical speeds. Depending on the command options available and the RA display, the response could be at the lowest end of the range or actually higher than commanded. This was confirmed in the data by the response accuracy shown in Table 23. In all cases, the response was at least the commanded value.

Table 23. Pilot Response Accuracy

Response Percent

< RA Rate of Climb	0
= RA Rate of Climb	46%
> RA Rate of Climb	54%

6.5 Simulation Validation

From the CCA perspective, one of the major goals of the CCA Technology Demonstration was to validate the simulation. With a validated simulation, additional studies can be conducted with a higher level of confidence in the results.

There actually are three CCA simulations: the Common Tool, the CCA Performance Simulation, and the SIL. Among its many functions, the Common Tool contains a simple dynamic model of the Proteus and G-III air vehicles. Scaled Composites provided the characteristics of the Proteus model shown in Table 24, and the Flight IPT used available business jet characteristics for the G-III model. The Flight IPT validated these models following the flights.

Table 24. Proteus Characteristics for Common Tool Simulation Model

Characteristic	Value
Vmin	90 KIAS
Vmax	160 KIAS
Roll rate	5 deg/sec
Roll acceleration	5 deg/sec/sec
Nz	2 g
Nz dot	0.05g/sec
Climb rate	max 3000 ft/min (highly dependent on ac configuration
	and weight)
Descent rate	max 2000 ft/min
Climb onset	accelerating at ~0.05g until commanded VSI obtained
Descent onset	accelerating at ~0.05g until commanded VSI obtained

The CCA Performance Simulation architecture is shown in Figure 6 and Figure 7. The CCA Performance Simulation contains representations of all the elements of the CCA system, plus dynamic models of the ownship and intruders. A complete description can be found in deliverable CCA008-Rev2, CCA Performance Simulation. The simulation has been validated against the technology demonstration flight data to the extent possible, given the quality of the data and time constraints on data analysis and simulation modifications. An attempt has been made to model, or at least to provide for, all primary effects.

The CCA SIL architecture, shown in Figure 13, is very similar to the CCA Performance Simulation. SIL components to be validated include the vehicle dynamics model and introduction of errors into the CCA sensors. Validation of the SIL against both the flight data and the CCA Performance Simulation is ongoing. Results of the SIL validation will be available after delivery of this report.

The simulation validation task has focused on validation of the CCA Performance Simulation against the Tech Demo data. The following subsections address validation of the CCA

Performance Simulation exclusively. Hence, for convenience, references hereafter to "the simulation" refer to the CCA Performance Simulation.

6.5.1 Approach

The approach taken to validate the simulation involved isolating each component and validating it separately, then validating the simulation as a whole. Validation comprised matching simulation results against the data from the flight runs selected as described in Section 6.5.2. Validation of the simulation components, ADS-B, TCAS, Data Link, Pilot, and Air Vehicle, is described in Sections 6.5.3 through 6.5.7.

6.5.2 Selected Runs

The Tech Demo runs selected to use for simulation validation are shown in Table 25. As described in Section 6.1.1, they were chosen based on (1) whether it would be feasible to replicate flight paths and TA and RA events in the simulation, and (2) the quality of the data. Given that the CCA Performance Simulation did not have all the Proteus and G-III vehicle characteristics parameters such as the airframe data and inner loop controller, many of these parameters were estimated and obtained from vehicles of similar type and size. Therefore, the simulated flight paths did not match perfectly with the actual path, especially upon a turn, climb, descend or roll maneuver. To replicate the flight paths and TA and RA events to the greatest extent possible, the runs with limited changes in altitude and turn maneuver (i.e., linear path) before an RA, were selected to minimize the differences between the real and simulated paths.

Table 25. Tech Demo Runs Used in Simulation Validation

Flight	Run		Geometry	Sensor / Advisory	Buffer	Delay	Climb Limit
375	1	1.01	Co-Heading, Co-Altitude	TGC	0	0	1000 fpm
375	2	2.01	Low-Aspect, Co-Altitude	TGC	0	0	1000 fpm
375	4	4.02	Abeam, Co-Altitude	TGC	4	0	2500 fpm
375	5	5.02	Head-On, Co-Altitude	TGC	4	0	2500 fpm
375	6	6.02	Head-On, Host Descending	TGC	4	0	2500 fpm
375	7	4.03	Abeam, Co-Altitude	TGC	2	0	2500 fpm
375	9	5.03	Head-On, Co-Altitude	TGC	2	0	2500 fpm
375	11	6.03	Head-On, Host Descending	TGC	2	0	2500 fpm
375	12	6.04	Head-On, Host Descending	TGC	0	0	2500 fpm
375	13	4.01	Abeam, Co-Altitude	TGC	6	0	2500 fpm
375	15	4.06	Abeam, Co-Altitude	TGC	4	2	2500 fpm
375	17	5.05	Head-On, Co-Altitude	TGC	0	0	2500 fpm
375	18	5.06	Head-On, Co-Altitude	TGC	4	2	2500 fpm
375	19	6.01	Head-On, Host Descending	TGC	6	0	2500 fpm
375	20	6.05	Head-On, Host Descending	TGC	0	0	2500 fpm
375	21	6.06	Head-On, Host Descending	TGC	4	2	2500 fpm
375	23	2.02	Low-Aspect, Co-Altitude	AGA	0	0	1000 fpm
370	2	4.14	Abeam, Co-Altitude	TRT	0	2	No Inhibit
370	6	6.13	Head-On, Host Descending	TRT	0	0	No Inhibit
370	7	6.14	Head-On, Host Descending	TRT	0	2	No Inhibit
369	2	3.03	Co-heading, Intruder Climbing	TRT	0	0	Climb Inhibit

369	6	4.10	Abeam, Co-Altitude	AGA	0	0	2500 fpm
369	7	5.09	Head-On, Co-Altitude	AGA	2	0	2500 fpm
369	13	4.07	Abeam, Co-Altitude	AGA	6	0	2500 fpm

6.5.3 CCA Sensor Performance

The CCA sensors used in the demonstration were ADS-B and TCAS II. Currently, each is modeled separately in the CCA Performance Simulation. In general, the CCA sensor errors can be modeled in terms of delay, missed data, and measurement error. Errors for each sensor type are modeled separately but in a somewhat similar manner, as described in the subsections below.

6.5.3.1 Characterizing Errors in the ADS-B Simulation Model

From the flight data analyses, the ADS-B sensor errors were analyzed and an assessment was made to determine if it was necessary to inject the errors into the simulation model so that it matched performance in the actual flight configuration.

As shown in Figure 24 and the more detailed timeline diagram in Appendix F, the ownship's ADS-B receives information on the position of the intruder at time t_0 , and the ownship's FMS records that position at time t_1 . This means that prior to time t_0 , the intruder arrived at a position (at time t_2), and the intruder's ADS-B recorded that position (at time t_1). (Times t_2 and t_1 are not shown in Figure 24.) Based on consultation with the ADS-B supplier, Garmin, we expected the delay between t_2 and t_0 to be about 200 msec. However, as explained in Section 6.2, a possible timing error prevented determination of the actual delay experienced during the demonstration. A provision for the delay is described below; however, for simulation validation against flight test, a delay of zero was used. Future studies will be able to enter a positive delay value for sensitivity studies.

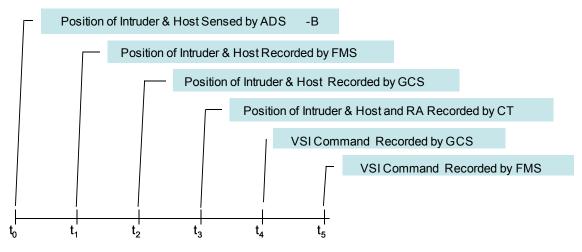


Figure 24. Timeline for ADS-B

To inject this delay in the simulation model, a delay function was added inside the CUB module as shown in Figure 25.

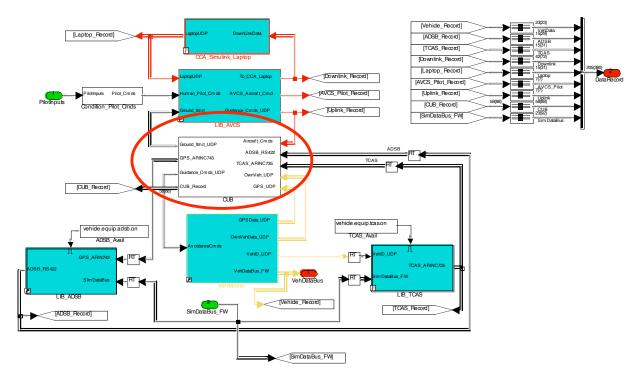


Figure 25. ADS-B Delay Insertion in CUB Model

However, in the CCA Performance Simulation, the vehicle frame rate is 100 Hz, while the sensor models such as the ADS-B and TCAS run at 1 Hz. The ADS-B model receives data from the GPS model, which is derived from the vehicle model. Due to the architecture setup and the runtime order of the components, the ADS-B data has an intrinsic lag of 1 second with respect to the vehicle model data as seen in the plot shown in Figure 26.

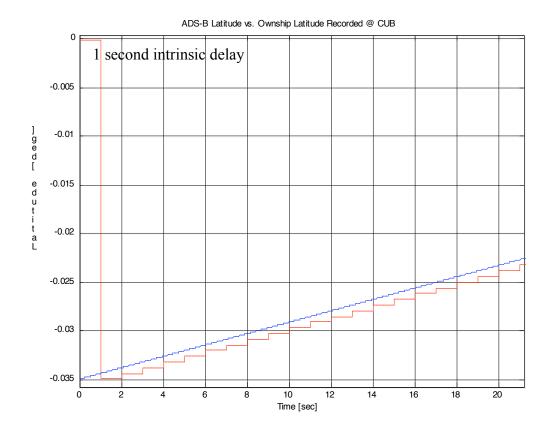


Figure 26. Plot Showing 1-second Intrinsic Delay of ADS-B Data

Another error to be characterized in the ADS-B model is missed data. In the ADS-B hardware, if there is no ADS-B message received for a tracked target, an extrapolated report is generated for that target. The Data Message Missed parameter from the ADS-B hardware indicates a missed message from the target. In its simulation counterpart, the NASA Langley ADS-B model generates the Data Message Missed discrete (Good_Send). This model is in fact a transmission and reception model, which is used to characterize the successful reception probability based on a number of inputs, such as ownship and intruder position data and other relevant data link parameters. The NASA Langley model purely drives the Good_Send discrete in the current ADS-B simulation model and there is currently no way to force the model to replicate the flight test Data Message Missed discrete. Given the fact that the ADS-B missed message rate is only 6.2%, there is no immediate need to inject such error into the simulation model for analysis. However, in the future a missed data block can be provided in the simulation by overriding the simulation Good_Send discrete with the Data_Msg_Missed discrete recorded in the flight test as shown in Figure 27.



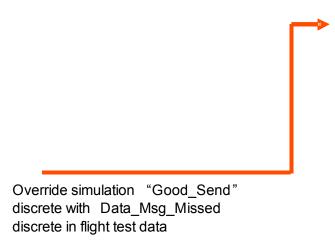


Figure 27. Future Insertion of a Missed Data Block

The source of measurement errors for ADS-B is GPS. The GPS errors can be injected into the simulation by utilizing the GPS model feature. When the GPS model is turned on, noise is added to the truth data, which is then subsequently processed by the ADS-B model. Since in simulation, the sources of "truth" data and ADS-B data are both from GPS, and the error for the G-III is clouded by data timing differences, for simplicity, the GPS feature is not used for both ownship and intruder vehicles.

To make the ADS-B simulation model perform more closely to the actual hardware, there are a couple suggestions that can be considered for future upgrades. First, the ADS-B pressure altitude should be quantized to have a 25-foot resolution, as in the ADS-B hardware. Second, the current ADS-B model does not have any logic to extrapolate the data upon a missed message. To solve this, it is recommended that an algorithm to extrapolate intruder data as in the hardware be implemented in future versions.

6.5.3.2 Characterize Errors in the TCAS Simulation Model

As with ADS-B, the TCAS sensor errors can be characterized in terms of delay, missed data, and sensed values. The analysis of the TCAS sensor errors, however, focused primarily on the sensed values, which play a significant role in the TCAS output data error. As mentioned in Sections 6.3.1 and 6.3.2, the TCAS missed update rate is undetermined and the TCAS-FMS delay is small (0.2 sec); therefore, the errors due to delay and missed data have not yet been modeled.

Unfortunately, the actual range and azimuth errors experienced in the flight test are also undetermined (Section 6.3.3 and Table 19) due to the timing issue between the G-III and Proteus instrumentation systems. However, since data is available, it was used to verify proper implementation of the range and bearing errors in the simulation.

The TCAS sensed values consist of the relative bearing, relative altitude, and range. From the flight test data analysis, the errors between the true and sensed flight data are calculated. The

mean and variance of these errors are then used in the performance simulation to model the TCAS noise. Figure 28 and Figure 29 show the "SensorNoise" blocks where the bias and variance parameters are utilized to model the hardware errors.

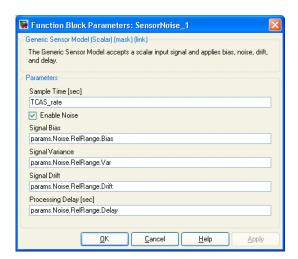


Figure 28. Sensor Noise Block

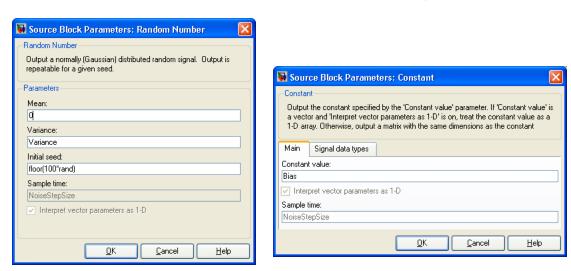


Figure 29. Sensor Noise Block Architecture

The purpose of adding errors to the relative bearing, relative altitude and range is to make these data match the actual values in the flight test such that the CAS logic would generate similar RAs in the simulation as in the actual flight test. Note that the sensor noise model shown in Figure 28 and Figure 29 is a generic Gaussian noise model, which assumes the bias is a constant. It is used to model the relative altitude and range errors. For the relative bearing, however, another type of noise model is utilized because the bias is a function of the range between the aircraft. Figure 30 shows the relative bearing sensor noise model, which outputs the bias based on the range input.

Figure 30. Relative Bearing Sensor Noise Block Architecture

In the CCA Performance Simulation, the errors between the true and sensed relative bearing and the corresponding range values are used in the lookup table such that the simulation sensed relative bearing has approximately the same error from the true relative bearing as in the flight test. The simulation is now set up to compute the range and azimuth error lookup values up to the time when the relative range is 0 nm. Ideally, the lookup values should be the same for all runs. Due to insufficient good data, no conclusion can be made whether the same look-up values can be used for all runs or if they vary based on geometry. As a result, these lookup values were computed for each individual run if the TCAS data is available. Figure 31 is an example of how the injected error allows the sensed relative bearing angle to have a similar error in simulation as in the actual hardware. The errors for the flight test and the simulation are similar. Please note that the time frame of Figure 31 only shows the azimuth plot up to 10 seconds before the range reaches 0 nm.

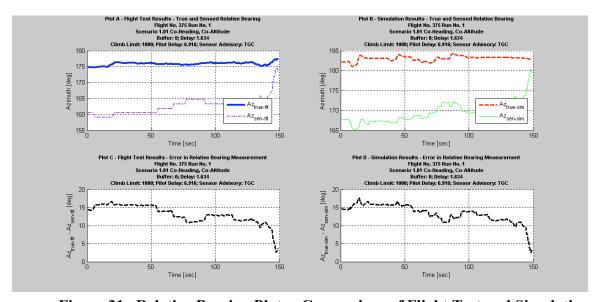


Figure 31. Relative Bearing Plots: Comparison of Flight Test and Simulation

In Figure 31, the values of relative bearing (azimuth) differ between flight test and simulation by about 8 degrees. This difference is the crab angle. During the flight test, the aircraft was crabbed into the wind; however, there is no wind in the simulation, so the aircraft is pointing in the same direction as its velocity vector.

To examine the azimuth accuracy in the simulation, a method for examining the true azimuth, expected true azimuth in simulation, crab angle, and the error bands for the true azimuth and expected true azimuth was derived for simulation validation. The definitions of the heading and bearing angles are depicted in Figure 32.

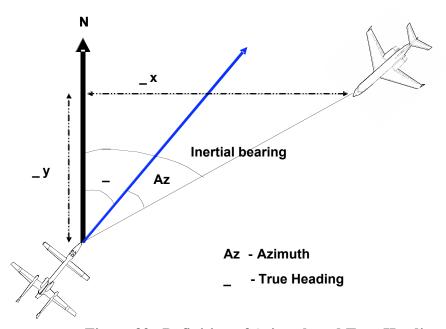


Figure 32. Definition of Azimuth and True Heading (No Crab Angle)

As seen in Figure 32, the true azimuth, or relative bearing, from the host to the intruder can be written as:

$$Az_{true} = \tan^{-1} \left(\frac{\Delta x_{true}}{\Delta y_{true}} \right) - \Psi_{true}$$
 (1)

where $\Delta x = longitudinal distance in ft$

 Δy = latitudinal distance in ft

 Ψ_{true} = true heading

The crab angle, which is the difference between the true heading and the velocity vector, is defined as:

$$crab_angle = \Psi_{true} - \Psi_{V_{NED}}$$
 (2)

where the heading of the velocity vector, Ψ_{Vned} can be calculated by taking the inverse tangent of velocity east divided by velocity north:

$$\Psi_{V_{NED}} = \tan^{-1} \left(\frac{V_E}{V_N} \right) \tag{3}$$

Apply equation (2) to equation (1) in simulation, the equation for the expected azimuth in simulation can be written as:

$$Az_{sim-NP \ ected} = \tan^{-1} \left(\frac{\Delta x}{\Delta y} \right) - \Psi_{V_{NED}}$$

$$Az_{simeNP \ ected} = \tan^{-1} \left(\frac{\Delta x}{\Delta y} \right) - \left(\Psi_{true} - crab_angle \right)$$

$$Az_{sim-NP \ ected} = \tan^{-1} \left(\frac{\Delta x}{\Delta y} \right) - \left[\tan^{-1} \left(\frac{\Delta x_{true}}{\Delta y_{true}} \right) - Az_{true} \right] + crab_angle$$

$$Az_{simeNP \ ected} = Az_{true} + crab_angle$$

$$(4)$$

Hardware errors also need to be taken into account for the azimuth accuracy analysis. Due to the GPS errors in the true position, the azimuth true angle should indeed be expressed in terms of a band of true azimuth. Applying a GPS error of 20 feet to both host and intruder GPS errors, the latitudinal and longitudinal errors in feet can be assumed to be $\sqrt{20^2 + 20^2} = 28.3 \, ft$. Assuming the measurement error of the heading, Ψ , to be approximately 2 degrees, the true azimuth error band equations can be written as:

$$Az_{error_band_upper} = \tan^{-1} \left[\frac{(\Delta x + \Delta x_{error})}{(\Delta y - \Delta y_{error})} \right] - \Psi + \Psi_{error}$$
(5)

$$Az_{error_band_lower} = \tan^{-1} \left[\frac{(\Delta x - \Delta x_{error})}{(\Delta y + \Delta y_{error})} \right] - \Psi - \Psi_{error}$$
(6)

where
$$\Delta x_{error} = 28.3 \text{ ft}$$

 $\Delta y_{error} = 28.3 \text{ ft}$
 $\Psi_{error} = 2 \text{ deg}$

Figure 33 shows the true azimuth error band, and the errors e_1 , e_2 , and e_3 , which represent the range from the sensed azimuth to the error band upper and lower bounds and the true azimuth. From equation 4, it is expected to see the azimuth in the simulation to differ from the truth azimuth by the crab angle. Given that the truth azimuth is a band and assuming the crab angle to have an error of ± 2 degrees, the expected azimuth in simulation can also be expressed as a band:

$$Az_{sim-xp\ ected} = Az_{true} \pm \frac{e_3 - e_1}{2} + crab_angle \pm 2\deg$$
 (7)

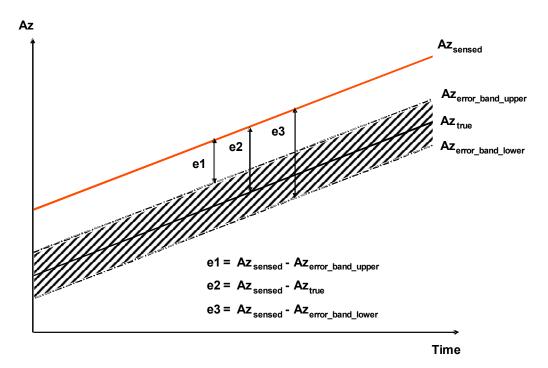


Figure 33. Definition of Azimuth Error Band, e₁, e₂, and e₃

Figure 34 further explains how the azimuth model should be validated. Note that the Az_{sim_exp} band should be around 4 degrees wider than the Az_{ture_flight} band due to the assumed crab angle error. To make a conclusion that the sensor model is validated, the true azimuth in simulation (Az_{true_sim}) should be close to Az_{sim_exp} and should lie within the band around Az_{sim_exp} . The second check is if the sensed azimuth in the flight test and simulation differ by approximately the crab angle.

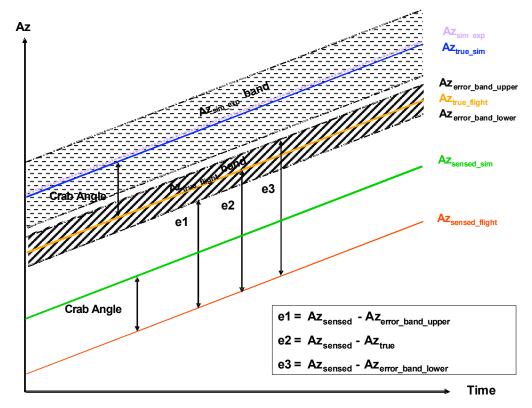


Figure 34. Azimuth Analysis to Validate Simulation

A successful example is demonstrated by the case of Flight 375 Run 1 in Figure 35 and Figure 36. Az $_{true_sim}$ follows closely with Az $_{sim_exp}$ and is within the band. In Figure 36, the sensed azimuth in simulation is greater than its counterpart in the flight test by approximately the crab angle.

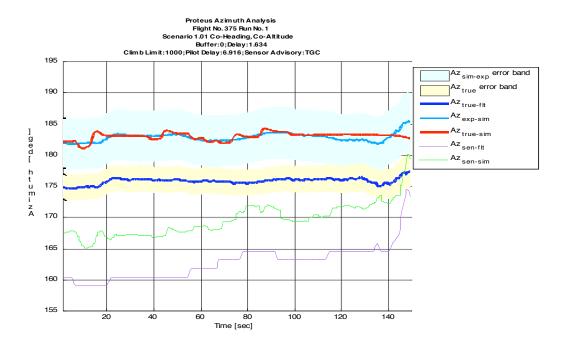


Figure 35. Flight 375 Run 1 – True Azimuth in simulation Is Within the Band Around Az_{sim_exp}

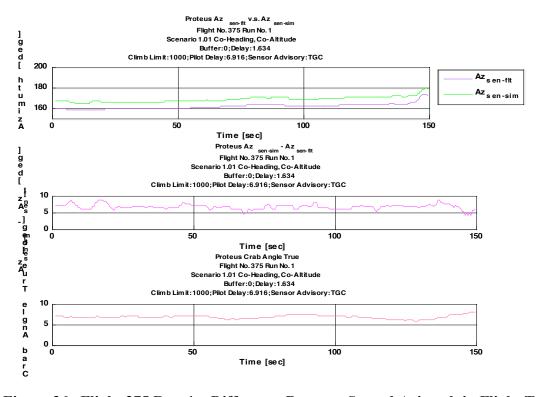


Figure 36. Flight 375 Run 1 – Difference Between Sensed Azimuth in Flight Test and Simulation Close to Crab Angle

6.5.4 TRT (Onboard TCAS Issuing Advisories) Results

Runs using TCAS as both sensor and maneuver advisory source provide important simulation validation information in two areas: the timeline for information starting with the ownship's CCA sensor, through the AVCS, and ending back at the ownship responding, and the time/range at which a resolution advisory (RA) is issued. The following sections describe use of this information to validate the simulation.

6.5.4.1 Timeline

The timeline information from the TRT runs can be used to model the delays associated with the pilot and the data link as well as to validate the total system delay. As shown in Figure 37 and in detail in Appendix F, we can follow an RA from the TCAS unit on board the ownship (issued at time t_0), through recording in the ownship's FMS (time t_1), transmission through the downlink to the GCS (recorded at time t_2), display and recording in the Common Tool (time t_3). We also see the pilot's reaction to the RA in the form of a VSI command entered at the GCS (time t_4), and follow it through the uplink to the FMS (time t_5). The aircraft's response can be seen in terms of elevator deflection and altitude change (time t_6).

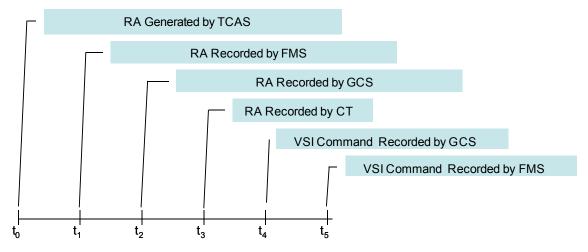


Figure 37. Timeline for TRT (TCAS-generated RA) Runs

Based on the data analysis (Section 6), we are confident that the time stamps for t_1 , t_3 , and t_5 provide both consistency and sufficient accuracy to derive approximations for the pilot affirmation time, the uplink and downlink delays, and the overall CCA system time, as shown in the equations below.

```
downlink time \approx t_3 - t_1 uplink time \approx downlink time pilot affirmation time \approx t_5 – uplink time – t_3 overall CCA system time \approx t_5 - t_1.
```

Validation of the data link times is described in Section 6.5.6, while validation of the pilot model is described in Section 6.5.5. The overall CCA system time could not be validated because the RAs were issued at significantly different times, as explained in Section 6.5.4.2, and of all the TRT runs listed in Table 25, the Rate of Climb RA's were all zeros.

6.5.4.2 RA Range

One way to validate that the TCAS simulation model is working as expected is to assess the range or time at which an RA is issued. For the TRT runs, we found that RAs were not issued at the same time in the technology demonstration that they were by the simulation. Table 26 provides the validation results.

Flight /		ology stration		mance lation	Difference		
Run	Time RA	Range to	S		Time RA	Range to	
	Issued, sec	Collision	Issued, sec	Collision	Issued, sec	Collision	
370-2	23.35 sec	~ 6593.1 ft	9.64 sec	~ 12293 ft	13.71 sec	5699.9 ft	
370-6	30.65 sec	~ 27078 ft	28.64 sec	~ 29000 ft	2.01 sec	1922 ft	
370-7	37.01 sec	~ 21814 ft	35.64 sec	~23100 ft	1.37 sec	1286 ft	
369-2	23.35 sec	~ 6693 ft	9.64 sec	~ 12405 ft	13.71 sec	5712 ft	

Table 26. RA Range Analysis

The significant differences between the technology demonstration data and the simulation presented in Table 26 imply that the TCAS model is not yet validated. Additional analysis and probably model improvements will need to be performed. The SIL can be used to support this future effort.

6.5.5 Pilot

The pilot model comprises a decision and a delay, or pilot affirmation time. The simulation currently provides for only the delay, as shown in Figure 38. In the future, a block can be added to set the decision to a percent probability of commanding what is advised and, if not, percent probability of commanding more or less than what is advised. The variable OwnshipData.equip.AVCS.PilotAffirm sets the pilot affirmation time in the CCA Performance Simulation.

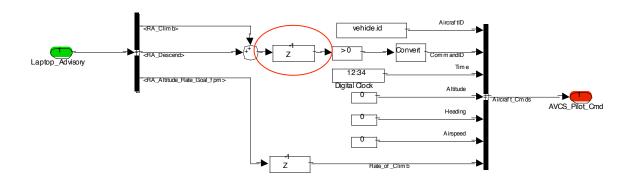


Figure 38. AVCS Pilot Model

To allow replication of the flight test runs, CCA Performance Simulation version 2.0 is set up to read the pilot affirmation time and delay in the excel spreadsheet TechDemoRuns.xls in the ..\Simulation\Flight_Demo_Matrices folder for each run.

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Figure 39. Injection of Pilot Affirmation Time and Delay

The pilot affirmation time data from Figure 23 was used in simulation. For those cases in which the data is not available, the average time of 5.94 sec was used, as shown in Figure 39. Figure 40, Figure 41, and Figure 42 show example comparisons of RA recording and VSI command between flight data and the simulation for a TRT case. Figure 43, Figure 44, and Figure 45 show an example comparison for a non-TRT case. Note that in Figure 43, the time difference between the first Sim VSI Cmd and the first Sim FMS Cmd is around 8.56 sec (128.2-119.64), which is very close to its counterpart in the flight test, 8.55 sec (126.852-118.3).

Proteus Time History Plot Flight No. 370 Run No. 2

Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

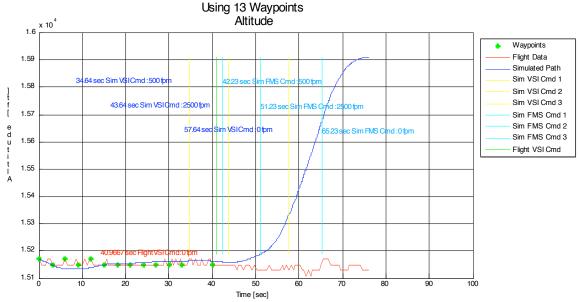


Figure 40. Flight 370 Run 2 - Proteus Altitude

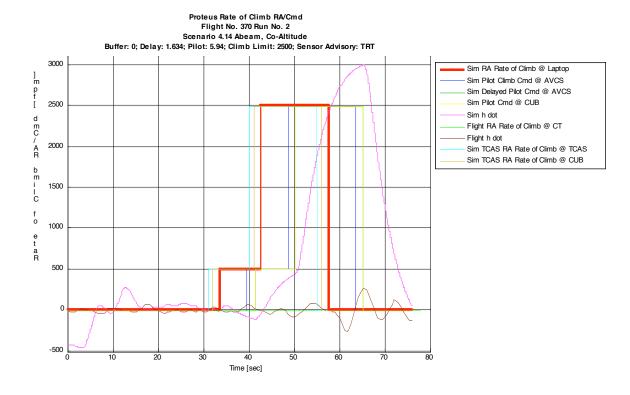


Figure 41. Flight 370 Run 2 - Rate of Climb RA / Command

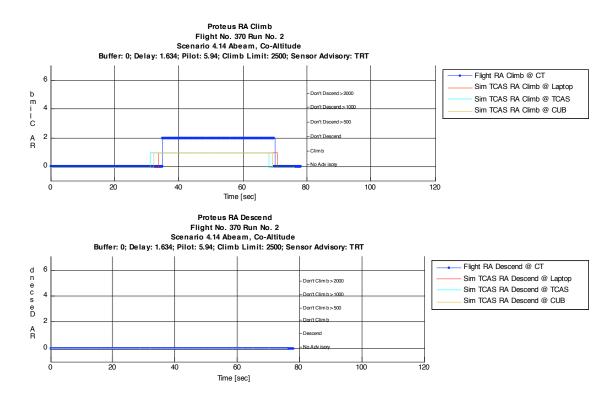


Figure 42. Flight 370 Run 2 - Resolution Advisories

Proteus Time History Plot

Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC Using 19 Waypoints Altitude 1.59 Waypoints Flight Data 1.58 Simulated Path Sim VSI Cmd 1 119.64 sec \$im VSICmd: 1000 fpm 1.57 Sim VSI Cmd 2 Sim FMS Cmd 1 145.64 sec Sim VSICmd:0 fpm 1.56 Sim FMS Cmd 2 Flight VSI Cmd Flight FMS Cmd 1.55 1.54 1.53 1.52 1.51 1.5 L 0 Time [sec]

Figure 43. Flight 375 Run 1 - Proteus Altitude

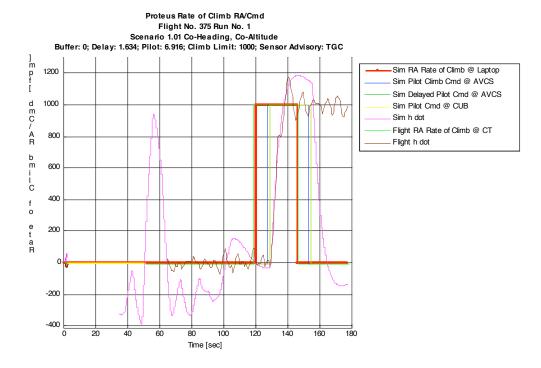


Figure 44. Flight 375 Run 1 - Rate of Climb RA / Command

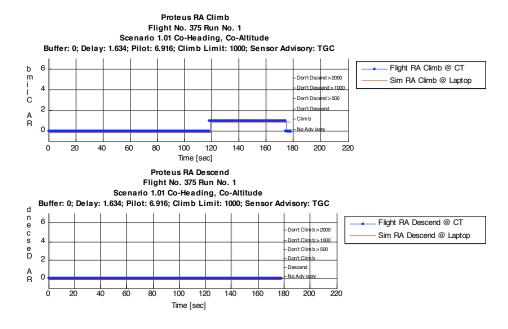


Figure 45. Flight 375 Run 1 - Resolution Advisories

6.5.6 Data Link

The data link consists of the downlink from the ownship to the AVCS and the uplink from the AVCS to the ownship. The simulation assumes that downlink and uplink times are constant throughout the run.

6.5.7 Ground CAS Logic

The Ground CAS Logic issues a maneuver advisory in the TGC and AGA cases. The same ground CAS logic software ran in the Common Tool during the Tech Demo and in the simulation. The correctness of its advisory can be validated by comparing it with the RA generated by the onboard TCAS unit in the TGC cases. In the TGC cases, the RAs generated by the onboard TCAS unit were recorded but not displayed. Figure 46 shows an example.

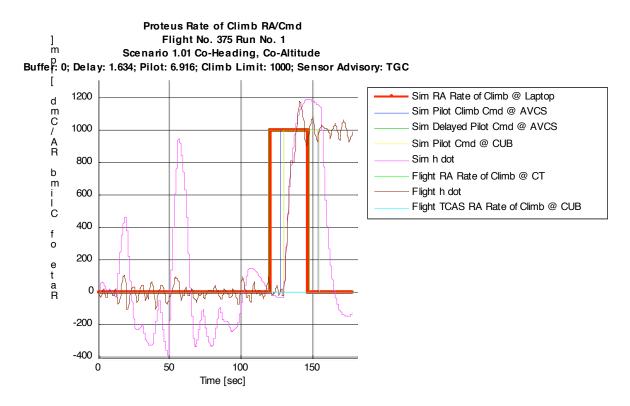


Figure 46. Flight 375 Run 1 - Rate of Climb RA/Command

It was expected that comparing RAs in the flight data with that in the simulation could validate the ground CAS logic. However, since the tracks in the technology demonstration were inconsistent, the advisories issued by the ground CAS logic often did not make sense. Rather than duplicating the tracking problem in the simulation, the simulation outputs from the ground CAS logic were only assessed for reasonableness and found to be as expected.

6.5.8 Air Vehicle Dynamics

Although validation of the ownship and intruder air vehicle models was the responsibility of the Flight IPT, the Proteus and G-III models in the CCA Performance Simulation needed to match the paths the vehicles followed in the Tech Demo well enough so that the other simulation components could be validated. To this end, waypoints for the vehicles were derived from the recorded positions of the vehicles. The G-III followed the waypoints for the entire flight, while the Proteus followed the waypoints up to the time when the ground pilot issued a VSI command. After the VSI command, the Proteus model reacted to the command, replicating the avoidance maneuver acceptably. A full description of the method used to force the simulated vehicles to

match the paths of the technology demonstration runs, as well as the model characteristics used, can be found in the CCA Performance Simulation User's Manual, Version 2.0, Section 4.

6.5.9 Comparison of Performance Simulation & SIL

Validation of the CCA Performance Simulation against the SIL has been planned but not yet executed. Each element will be isolated, errors will be injected as inputs to the hardware, and timelines will be validated.

7 Summary and Conclusions

The test planning, flight operations, data reduction, and simulation validation stages performed for the FY05 CCA Technology Demonstration all provided valuable data on UAS collision avoidance system performance. The process also yielded valuable insights into how dependent the stages are to each other and how better to perform each process in order to improve the quality and efficiency of subsequent efforts. Many insights have been gained; so the goal of this section is to pass the lessons on to possibly facilitate future UAS development efforts. Additionally, due to Access 5 programmatics, the project has been terminated before many of the analysis and simulation validation efforts could be completed. The CCA Work Package had developed a plan outlining simulation validation and other technology demonstration data analysis efforts that were not performed due to insufficient time. This information also is expressed in this document to help future UAS collision avoidance system efforts to focus their work.

7.1 Lessons Learned

While many of the items below may be better termed 'lessons relearned', the CCA Work Package feels it is still necessary to reemphasize several key items because of the impact they can have on successful conduct of a test effort.

7.1.1 UAS Collision Avoidance Systems

- Current collision avoidance systems will need to be adapted for UAS operations or new systems developed. Perhaps the most important lesson learned during the flight demonstration is that UAS operations have several unique challenges that will require significant changes to existing and emerging systems to maintain an equivalent level of safety to manned aircraft. Without the ability to visually acquire an intruder aircraft, it is critical that the collision avoidance recommendation presented by the system is timely and even more importantly accurate. Furthermore, the system needs to integrate well into current operations in the NAS and not adversely impact the operation of systems now in
- Data latency may force the pilot out of the decision process. The TCAS system currently used has an expected pilot reaction time imbedded in the logic. UAS beyond line of sight communication delays may be equal to or greater than the maximum delay acceptable to today's systems. The options available are to design a system to provide information to the pilot sooner or to autonomously respond to a maneuver recommendation.

7.1.2 Test Planning

- Establish and maintain a realistic timeline. This demonstration was conducted on a compressed timeline that forced several efforts to be performed in parallel. When delays occur, the test team and project management must be prepared to shift the entire remaining timeline rather than compress subsequent efforts.
- Ensure close coordination between all team members. This is important for identifying any problems that might arise during the test and working through proper solutions prior to data-collection flights.
- Ensure the Data Analysis Plan (DAP) completely captures each required data parameter and fully details the required accuracy. Successful completion of the DAP ties in closely

with the two previous lessons. It is important that the people who are going to use the data for analysis have a good knowledge of the data collection process in order to ensure all the necessary information is present. A well laid out timeline will provide enough time to fully outline expected analysis results and coordinate with flight test personnel.

- Use multiple, accurate sources of truth and timing data in order to characterize latency and sensor measurement errors. For example, truth data for the G-III relied on TSPI data for which the time stamp was inconsistent with sensor data recorded on the ownship, resulting in lack of complete conclusions about CCA sensor characteristics. Recording the G-III's ADS-B data would have provided another data source to help track down the inconsistency and possibly an alternate method of deriving the G-III's truth data.
- The test schedule should allow evaluation of data quality between flights. When command and control link quality was poor during a flight, test runs continued primarily to meet the project schedule. This resulted in data that was of little use. Also, a software error that resulted in intruders not being tracked properly was identified but not fixed during the testing; resulting in data that required extra processing and in some cases was not useful. Early review of these problems may have resulted in more useful data.

7.1.3 Flight Operations

- Ensure all team members, including the technology developer, are represented on test day. The technology developer must be present and available during the demonstration flights to assess data quality and to address any concerns regarding the quality of the data collected.
- Clearly define test performance standards. This demonstration used encounter geometries to generate near-collision scenarios. Simulation of the runs was complicated by maneuvers flown during the encounter to ensure the aircraft passed each other at the specified test parameters when emphasis should have been placed on maintaining a stable approach that would have facilitated model validation.

7.1.4 Data Reduction

- Data responsibilities must be clearly defined during the planning stage. This is necessary for building and testing the software processes and data storage structures in a timely manner and avoiding post-flight processing delays.
- Data delivery schedules must be established and followed. Timeline compression caused by delays in data delivery can seriously affect data analysis quality.
- Data reduction cannot start with delivery of the first set of test data. It is critical that the test team prepare sample data sets prior to actual flight operations to test data handling and reduction. This can mitigate problems caused by an incomplete parameter list in the DAP and by actual data collection errors. If sample data is not available, allow time to perform a preliminary assessment of the data from the first flight before continuing.

7.1.5 Laboratory Testing to Support the Flight Test

• Test the closed-loop system in the lab with representations of all flight software and hardware and an accurate model of the vehicle dynamics prior to flight test. Due to time constraints and low safety risk, these activities were performed in parallel. Given access to the flight software and/or logic, the problem with TCAS intruder tracking seen in flight test would have been identified through lab testing and corrected prior to the flights.

• The SIL was used during the flight demonstration to debug issues such as the TCAS ID and to update filters in the ground CAS logic. Sample flight data recorded from test flight would have aided in discovery of the filter deficiencies and allowed for more robust software to be used throughout all of the flight tests.

7.1.6 Simulation Validation

- Isolation of the model components allows each system element to be validated with minimal interference from the other components.
- Direct injection of flight test data into the simulation allows for the easiest replication of the flight. In the future, one helpful simulation improvement would be to bypass the vehicle model and use truth position, velocity, and orientation data instead of generating waypoints to follow.

7.2 Future Work

7.2.1 Complete the Data Analysis

- Perform additional analyses other than simulation validation, including
 - o Did the look-ahead buffer compensate for BLOS data link delay?
 - How did BLOS data link delay affect the CCA system?
 - o Compare TGC and TRT to assess the adequacy of a ground CAS algorithm.
 - System latency.
- Validate the simulation with alternate flight test data as available. Requires accurate "truth" data for intruder.
 - Will allow validation of ADS-B intruder-host message latency, range error, and azimuth error.
 - Will allow validation of TCAS missed update rate, range error, azimuth error, and relative altitude error.
- Validate the CCA Performance Simulation against the SIL
 - o Complete TCAS and ADS-B model validation
 - o Ensure that these two simulations are the same and hence can both be used for future analyses.
- Validate the SIL against flight demo data. This effort is in progress but needs to be completed and documented.

7.2.2 Pilot and Display

- Characterize a more accurate pilot model. The flight test was not conducted under operational conditions, there were only three ground pilots, and a select set of encounters was flown. Broader testing can be performed in the SIL and the AVCS.
- Validate the CCA display, per FSTO-3. Data could be collected via testing in the SIL.
- Add pilot decision to the pilot model in the simulation.

7.2.3 CCA Sensors

• TCAS:

- o Analyze RA time/range mismatch between simulation and flight data. Explain the source of the mismatch and, if appropriate, update the simulation model.
- o Analyze altitude discrepancies observed between TCAS data and GPS data.
- Characterize the effects of the relative altitude measurement.

ADS-B model:

- o Insert a missed data block by overriding the simulation Good_Send discrete with the Data Msg Missed discrete recorded in the flight test.
- o Implement an algorithm to extrapolate the data upon a missed message as in the hardware.
- Quantize the ADS-B pressure altitude to have a 25-ft resolution, as in the ADS_hardware.

7.2.4 Simulation-Based Sensitivity Studies

- Use the CCA Performance Simulation and the SIL to perform sensitivity studies on the various component characteristics and through a larger variety of encounter scenarios. Create a detailed test plan that supports using the results of the studies for safety analysis and specification of performance requirements.
- Create generic CCA sensor models for use in broader sensitivity studies and in the AVCS. Interface these models to the simulation. Allow for alternate collision avoidance logic.

8 Definitions and Acronyms

8.1 Definitions

Alert – Indication (aural or visual) that provides information to the flight crew in a timely manner about a converging aircraft or a potential collision.

Cooperative Traffic – Traffic that broadcasts position or other information, which assists in detecting and assessing conflict potential.

Manned Aircraft – Aircraft that are piloted by a human onboard.

Resolution Advisory (RA) – Aural voice and display information provided by TCAS-II, advising that a particular maneuver should, or should not, be performed to attain or maintain safe separation distance from an intruder aircraft.

Sense and Avoid – The ability to sense traffic which may create a conflict, evaluate flight paths, determine traffic right-of-way, and maneuver to avoid other traffic.

Threat – An intruder aircraft that has satisfied the threat detection logic and thus requires an avoidance maneuver

Traffic – Any air vehicles that might be encountered by the UA.

Traffic Advisory (**TA**) – A TCAS-II message given to alert a pilot that another aircraft is within detection range.

UAS – Unmanned Aircraft System. This includes the UA, the ground control station (which includes the human pilot), and all associated communications hardware.

8.2 Acronym List

ADS-B	Automatic Dependent Surveillance-Broadcast
CA	Collision Avoidance
CCA	Cooperative Collision Avoidance
CAS	Collision Avoidance System
DoD	Department of Defense
FAA	Federal Aviation Administration
FMS	Flight Management System
FRD	Functional Requirements Document
FSTO	Flight (test) Specific Test Objective
G-III	Gulfstream III aircraft
GCS	Ground Control Station
HALE	High Altitude, Long Endurance
MOA	Military Operating Area
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
OPV	Optionally Piloted Vehicle
RA	Resolution Advisory (see Definitions)
ROA	Remotely Operated Aircraft
SIL	Systems Integration Lab
TA	Traffic Advisory (see Definitions)
TCAS	Traffic Alert and Collision Avoidance System
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System

Appendices A-G can be found in separate files.

Appendix A - Mapping of CCA Objectives to Data Analyses

Objective Number	Question	Value / Validity	Record	Analyze
CGTO-1	Determine effective azimuth accuracy	High. Validates simulation model of TCAS.	Host location and Euler angles Intruder location TCAS or ADS-B data from box	Calculate true azimuth from host to intruder; band with GPS error. Plot time history of azimuth and sensed azimuth; compare. Develop error band for sensed azimuth.
	Determine effective relative altitude accuracy	More applicable for the sensors we used.	Host and Intruder Altitudes TCAS or ADS-B data from box	Compare true altitude difference with sensed altitude difference.
	Determine effective elevation accuracy	High. Validates simulation model of TCAS.	Host location and Euler angles Intruder location TCAS or ADS-B data from box	Calculate true elevation from host to intruder; band with GPS error. Plot time history of elevation and sensed elevation compare. Develop error band for sensed elevation.
	Situational awareness provided to pilot?	High. Answers subquestion, was data provided to pilot?	TCAS or ADS-B data coming out of box TCAS or ADS-B data from DL and @ display	Compare TCAS or ADS-B data from all recording points to ensure they're the same.
		High. Answers question subjectively.	Pilot questionnaire.	"Were you aware?"
CGTO-2	Track detected cooperative traffic?	Medium. Answers question, but multiple intruders, which are necessary for potentially confusing tracks, are not anticipated.	intruder location host location TCAS or ADS-B data coming out of box TCAS or ADS-B data from DL and @ display	Plot comparison of true and sensed intruder location relative to host for time range(s) when traffic was detected to ensure that traffic was tracked. Flag any missing sensed data. If multiple intruders available, flag any data points that assign wrong intruder number. Summarize any flagged data.
	Is time and position of intruder tracked?	High. Answers question outright.	data at display with track IDs	Is a 1-sec update enough?
	Provide position information to the pilot?	High. Answers questions outright.	intruder location host location TCAS or ADS-B data @ display	Compare time history of intruder position with that recorded from display.
			Pilot questionnaire.	Was display of traffic position working?

Objective Number	Question	Value / Validity	Record	Analyze
CGTO-2	Could the pilot track the data?	Medium. Could be a function of the test.	Pilot questionnaire.	Could you track the intruders?
	Determine track accuracy of sensed time and position of intruder	High. Provides insight into aggregate position accuracy given all the latencies in the system. However, TCAS installation is expected to produce best-possible results, so this data only bounds TCAS accuracy at the "good" end.	intruder location host location TCAS or ADS-B data coming out of box TCAS or ADS-B data from DL and @ display	Plot comparison of true and sensed intruder location relative to host as a function of time (or time tag) for time range(s) when traffic was detected. Assess time differential against expected data latency between each point. Compare true and sensed position (without adjusting for the time differential) by plotting difference as a function of time (or time tag) and by calculating statistical data (mean, standard deviation) of difference. Compare statistical data on difference against expected errors for the equipment.
		High. Validates simulation model.	intruder location host location TCAS or ADS-B data coming out of box TCAS or ADS-B data from DL and @ display	Latency assessment. Characterize time delay between true and displayed intruder location.
CGTO-3	Determine collision potential with detected cooperative traffic	Medium. Answers question of did system perform as expected, but tests are limited in quantity.	For each alert and warning, what were the conditions (range, bearing, relative altitude, closing velocity, vertical velocity)	How does range and/or time at which advisory was issued compare with that expected from onboard TCAS II?
	Provide notification of potential collision to pilot?	Low	All advisories at display	Plot time history of advisories. Was a maneuver advisory preceded by an alert?
	Observe information presented to the ROA pilot that conveys collision potential	Low	Alerts (visual and aural) @ display Tester observations	Run data through display software post-test if necessary to observe.

Objective Number	Question	Value / Validity	Record	Analyze
CGTO-3	Demonstrate utility of the CCA subsystem alert that notifies the ROA pilot of a potential collision threat	Low	Pilot behavior	May be difficult to glean, except through scribe notes and pilot VSI commands.
CGTO-4	Demonstrate the utility of a CCA subsystem recommended evasive maneuver	Medium. Partially a function of the test.	In cases in which we had a 2nd climb command, record intruder location host location	Why was there a 2nd climb command?
CGTO-5	Determine the time required for the ROA pilot to perform an evasive maneuver after the CCA subsystem has notified the ROA pilot of a potential collision	Low. Gives some indication of pilot response model, but these are ideal conditions.	Alert Pilot command at GCS	Pilot response time
CGTO-6	Demonstrate the ability to assess the adequacy of the maneuver and determine that the collision potential has been avoided	High. Answers questions outright.	All Clear signal intruder location host location	Was an "all clear" given after the collision potential passed?
	Determine that the evasive maneuver maintains separation from the threat aircraft	High. Answers question outright.	All Clear signal intruder location host location	Miss distance; Plot relative locations with time, and assess unexpected maneuvers.

Appendix B – Parameter Lists

Flight 369+ FMS Parameter List

Field	Parameter	Description/Units	
1	ElapsedTime[sec]	Elapsed Time, seconds	
2	msg270010cnt	message 27 10Hz counter	
3	LAIL	left aileron position, deg	
4	PTRIM	pitch trim position, deg	
5	ELEV	elevator position, radians	
6	msg270001cnt	message 27 1Hz counter	
7	LRUD	left rudder position, deg	
8	msg760010cnt	message 76 10Hz counter	
9	LPLA	left power lever angle, deg	
10	RPLA	right power lever angle, deg	
11	msg340001cnt	message 34 1Hz counter	
12	TOAT	Total temperature, deg F	
13	GPS_Lat	Aircraft latitude, degrees	
14	GPS_Long	Aircraft longitude, degrees	
15	GPSTrack	Aircraft ground track, deg magnetic	
16	GPSGSpd	Aircraft ground speed, knots	
17	GPSDistNextWpt	GPS Distance to next waypoint, nmi * 10	
18	msg220010cnt	message 22 10Hz counter	
19	APENGAGE	Autopilot engage status, VDC (on > 2.5 VDC)	
20	msg340010cnt	message 34 10Hz counter	
21	INS_Pitch	Aircraft Pitch Attitude, degrees (negative is nose down)	
22	INS_Roll	Aircraft roll attitude, degrees (right roll is positive)	
23	INS_Heading	Aircraft Heading relative to True North (positive values represent clockwise angle relative to North)	
24	INS_Lat	Aircraft Latitude, degrees (referenced to WGS-84 map datum)	
25	INS_Lon	Aircraft Longitude, degrees (referenced to WGS-84 map datum)	
26	INS_Altitude	Aircraft altitude, feet (referenced to WGS-84 map datum)	
27	INS_mode	INS Mode (1 = Test, 2 = Init, 3 = (Not Used), 4 = Fine Alignment, 5 = Air Alignment, 6 = Transfer Alignment, 7 = Air Navigation, 8 = Land Navigation, 9 = GPS Only)	
28	INS_VeIN	Velocity North, ft/sec	
29	INS_VelE	Velocity East, ft/sec	
30	INS_VeID	Velocity Down, ft/sec	
31	PSTAT1	Static pressure, psf	
32	PDYN1	Dynamic pressure, psf	
33	msg220001cnt	message 22 10Hz counter	
34	TM_CMD_HDG	GCS commanded aircraft heading, degrees true	
35	TM_CMD_ALT	GCS commanded aircraft altitude, feet (WGS84 datum)	
36	TM_CMD_VSI	GCS commanded rate of climb/descent, ft/min	
37	TM_Direct_Cmd	Counter incremented with each new GCS "Direct" command	
38	msg850010cnt	message 85 10Hz counter	
39	ADSB_INT	ADSB Number of Intruders (maximum of 3)	
40 41	ADSBTmeP	ADS-B Host Time Stamp, Seconds since UTC midnight ADS-B Intruder 1 Vehicle ID , 0 to 2E24	
	ADSBInt1	·	
42	ADSBLat1	ADS-B Intruder 1 Latitude, WGS84 deg	

Field	Parameter	Description/Units	
43	ADSBLng1	ADS-B Intruder 1 Longitude, WGS84 deg	
44	ADSBAlt1	ADS-B Intruder 1 Altitude, pressure altitude ft	
45	ADSBVVI1	ADS-B Intruder 1 Vertical Velocity, ft/min (up is positive)	
46	ADSBLMR1	ADS-B Intruder 1 Data Message Missed, (TRUE = Data contained in report	
		is extrapolated	
		FALSE = Actual message contained in report)	
47	ADSBInt2	ADS-B Intruder 2 Vehicle ID , 0 to 2E24	
48	ADSBLat2	ADS-B Intruder 2 Latitude, WGS84 deg	
49	ADSBLng2	ADS-B Intruder 2 Longitude, WGS84 deg	
50	ADSBAlt2	ADS-B Intruder 2 Altitude, pressure altitude ft	
51	ADSBVVI2	ADS-B Intruder 2 Vertical Velocity, ft/min (up is positive)	
52	ADSBLMR2	ADS-B Intruder 2 Data Message Missed, (TRUE = Data contained in report	
		is extrapolated	
	4 D O D I = 40	FALSE = Actual message contained in report)	
53	ADSBInt3	ADS-B Intruder 3 Vehicle ID , 0 to 2E24	
54	ADSBLat3	ADS-B Intruder 3 Latitude, WGS84 deg	
55	ADSBLng3	ADS-B Intruder 3 Longitude, WGS84 deg	
56	ADSBAlt3	ADS-B Intruder 3 Altitude, pressure altitude ft	
57	ADSBVVI3	ADS-B Intruder 3 Vertical Velocity, ft/min (up is positive)	
58	ADSBLMR3	ADS-B Intruder 3 Data Message Missed, (TRUE = Data contained in report	
		is extrapolated	
59	ADSBPRTS	FALSE = Actual message contained in report) ADS-B Host Vehicle ID, 0 to 2E24	
	ADSBLatP	·	
60		ADS-B Host Latitude, WGS84 deg	
61	ADSBLngP	ADS-B Host Longitude, WGS84 deg	
62	ADSBAltP	ADS-B Host Vertical Velocity of Improvious	
63	ADSBVVIP	ADS-B Host Vertical Velocity, ft/min (up is positive)	
64	ADSBLMRP	ADS-B Host Data Message Missed, (TRUE = Data contained in report is extrapolated	
		FALSE = Actual message contained in report)	
65	ADSBTme1	ADS-B Intruder 1 Time Stamp, Seconds since UTC midnight	
66	ADSBTme2	ADS-B Intruder 2 Time Stamp, Seconds since UTC midnight	
67	ADSBTme3	ADS-B Intruder 3 Time Stamp, Seconds since UTC midnight	
68	msg860010cnt	message 86 10Hz counter	
69	TCAS INT	TCAS Number of Intruders (maximum of 3)	
70	RA_Climb	Host TCAS RA Climb, Range: 0 to 7	
		2 = Climb	
71	RA Dscnd	Host TCAS RA Descend, Range: 0 to 7	
		2 = Descend	
72	RA AltRt	Host TCAS RA Altitude Rate Goal, ft/min	
73	RA_VrtCt	Host TCAS RA Vertical Control, Range: 0 to 7	
74	RA_CmbCt	Host TCAS RA Combined Control, Range: 0 to 7	
		0 = No Advisory	
		1 = Up Advisory Corrective	
		3 = Preventive	
		4 = Clear of Conflict	
		5 = Down Advisory Corrective	
75	TCASInt1	TCAS Intruder 1 ID, set to 2 on aircraft	

Field	Parameter	Description/Units	
76	TCASTme1	TCAS Intruder 1 Timestamp, seconds since UTC midnight	
77	TCASRng1	TCAS Intruder 1 Relative Range, nmi	
78	TCASBrg1	TCAS Intruder 1 Relative Bearing, deg	
79	TCASRAI1	TCAS Intruder 1 Relative Altitude, ft	
80	TCASArr1	TCAS Intruder 1 Display Arrow, 0 = None	
		1 = Up	
		2 = Down	
81	TCASACd1	TCAS Intruder 1 Advisory Code, 0 = Other Traffic	
		1 = Potential Threat	
		2 = Threat	
00	TO 4 O I = 40	3 = Proximate Traffic	
82	TCASInt2	TCAS Intruder 2 ID, set to 3 on aircraft	
83	TCASTme2	TCAS Intruder 2 Timestamp, seconds since UTC midnight	
84	TCASRng2	TCAS Intruder 2 Relative Range, nmi	
85	TCASBrg2	TCAS Intruder 2 Relative Bearing, deg	
86	TCASRAI2	TCAS Intruder 2 Relative Altitude, ft	
87	TCASArr2	TCAS Intruder 2 Display Arrow, 0 = None 1 = Up	
		2 = Down	
00	TO A O A O -10		
88	TCASACd2	TCAS Intruder 2 Advisory Code, 0 = Other Traffic 1 = Potential Threat	
		2 = Threat	
		3 = Proximate Traffic	
89	TCASInt3	TCAS Intruder 3 ID, set to 4 on aircraft	
90	TCASTme3	TCAS Intruder 3 Timestamp, seconds since UTC midnight	
91	TCASRng3	TCAS Intruder 3 Relative Range, nmi	
92	TCASBrg3	TCAS Intruder 3 Relative Bearing, deg	
93	TCASRAI3	TCAS Intruder 3 Relative Altitude, ft	
94	TCASArr3	TCAS Intruder 3 Display Arrow, 0 = None	
		1 = Up	
	<u> </u>	2 = Down	
95	TCASACd3	TCAS Intruder 3 Advisory Code, 0 = Other Traffic	
		1 = Potential Threat	
		2 = Threat	
96	TCASSSM1	3 = Proximate Traffic Host TCAS Intruder 1 Data Status, 0 = Failure Warning	
90	I OAGGGIVI I	1 = Functional Test	
		2 = No Computed Data	
		3 = Normal Operation	
97	TCASSSM2	Host TCAS Intruder 2 Data Status, 0 = Failure Warning	
		1 = Functional Test	
		2 = No Computed Data	
	TO A CO CO 40	3 = Normal Operation	
98	TCASSSM3	Host TCAS Intruder 3 Data Status, 0 = Failure Warning 1 = Functional Test	
		2 = No Computed Data	
		3 = Normal Operation	
L		The state of the s	

Source: Scaled Composites data file, Flt369_A5_FMS_Channel_List.xls

Flight 369+ GCS Parameter List

Field	Parameter	Description/Units	
1	GPS16TIME	GPS Time, HHMMSS	
2	PSTAT1	Static pressure, psf	
3	PDYN1	Dynamic pressure, psf	
4	INS PitchAttitude1	Aircraft Pitch Attitude, degrees (negative is nose down)	
5	INS RollAttitude1	Aircraft roll attitude, degrees (right roll is positive)	
6	INS_HeadingTrue1	Aircraft Heading relative to True North (positive values represent clockwise angle relative to North)	
7	INS_Lat1	Aircraft Latitude, degrees (referenced to WGS-84 map datum)	
8	INS_Long1	Aircraft Longitude, degrees (referenced to WGS-84 map datum)	
9	INS_Altitude1	Aircraft altitude, feet (referenced to WGS-84 map datum)	
10	INS_mode	INS Mode (1 = Test, 2 = Init, 3 = (Not Used), 4 = Fine Alignment, 5 = Air Alignment, 6 = Transfer Alignment, 7 = Air Navigation, 8 = Land Navigation, 9 = GPS Only)	
11	INS_VeIN	Velocity North, ft/sec	
12	INS_VeIE	Velocity East, ft/sec	
13	INS_VeID	Velocity Down, ft/sec	
14	TM_CMD_HDG	GCS commanded aircraft heading, degrees true	
15	TM_CMD_ALT	GCS commanded aircraft altitude, feet (WGS84 datum)	
16	TM_Hdg_mode	Discrete, on when GCS pilot engages autopilot	
17	TM_Dir_Msg_Num	Counter incremented with each new GCS "Direct" command	
18	TCAS_INT	TCAS Number of Intruders (maximum of 3)	
19	RA_AltRt	Host TCAS RA Altitude Rate Goal, ft/min	
20	RA_Climb	Host TCAS RA Climb, Range: 0 to 7 4 = Climb	
21	RA_CmbCt	Host TCAS RA Combined Control, Range: 0 to 7 0 = No Advisory 1 = Up Advisory Corrective 3 = Preventive 4 = Clear of Conflict 5 = Down Advisory Corrective	
22	RA_Dscnd	Host TCAS RA Descend, Range: 0 to 7 4 = Descend	
23	RA_VrtCt	Host TCAS RA Vertical Control, Range: 0 to 7	
24	TCASInt1	TCAS Intruder 1 ID, set to 2 on aircraft	
25	TCASTme1	TCAS Intruder 1 Timestamp, seconds since UTC midnight	
26	TCASRng1	TCAS Intruder 1 Relative Range, nmi	
27	TCASBrg1	TCAS Intruder 1 Relative Bearing, deg	
28	TCASRAI1	TCAS Intruder 1 Relative Altitude, ft	
29	TCASArr1	TCAS Intruder 1 Display Arrow, 0 = None 1 = Up 2 = Down	
30	TCASACd1	TCAS Intruder 1 Advisory Code, 0 = Other Traffic 1 = Potential Threat 2 = Threat 3 = Proximate Traffic	

Field	Parameter	Description/Units	
31	TCASSSM1	Host TCAS Intruder 1 Data Status, 0 = Failure Warning	
		1 = Functional Test	
		2 = No Computed Data	
		3 = Normal Operation	
32	TCASInt2	TCAS Intruder 2 ID, set to 3 on aircraft	
33	TCASTme2	TCAS Intruder 2 Timestamp, seconds since UTC midnight	
34	TCASRng2	TCAS Intruder 2 Relative Range, nmi	
35	TCASBrg2	TCAS Intruder 2 Relative Bearing, deg	
36	TCASRAI2	TCAS Intruder 2 Relative Altitude, ft	
37	TCASArr2	TCAS Intruder 2 Display Arrow, 0 = None	
		1 = Up	
20	TOAGAGAG	2 = Down	
38	TCASACd2	TCAS Intruder 2 Advisory Code, 0 = Other Traffic 1 = Potential Threat	
		2 = Threat	
		3 = Proximate Traffic	
39	TCASSSM2	Host TCAS Intruder 2 Data Status, 0 = Failure Warning	
		1 = Functional Test	
		2 = No Computed Data	
		3 = Normal Operation	
40	TCASInt3	TCAS Intruder 3 ID, set to 4 on aircraft	
41	TCASTme3	TCAS Intruder 3 Timestamp, seconds since UTC midnight	
42	TCASRng3	TCAS Intruder 3 Relative Range, nmi	
43	TCASBrg3	TCAS Intruder 3 Relative Bearing, deg	
44	TCASRAI3	TCAS Intruder 3 Relative Altitude, ft	
45	TCASArr3	TCAS Intruder 3 Display Arrow, 0 = None	
		1 = Up 2 = Down	
46	TCASACd3	TCAS Intruder 3 Advisory Code, 0 = Other Traffic	
40	TOAGACUS	1 = Potential Threat	
		2 = Threat	
		3 = Proximate Traffic	
47	TCASSSM3	Host TCAS Intruder 3 Data Status, 0 = Failure Warning	
		1 = Functional Test	
		2 = No Computed Data	
40	ADOD INT	3 = Normal Operation	
48	ADSB_INT	ADSB Number of Intruders (maximum of 3)	
49	ADSBAItP	ADS-B Host Altitude, pressure altitude ft	
50	ADSBLMRP	ADS-B Host Data Message Missed, (TRUE = Data contained in report is	
		extrapolated	
51	ADSBLatP	FALSE = Actual message contained in report)	
52	ADSBLngP	ADS-B Host Latitude, WGS84 deg ADS-B Host Longitude, WGS84 deg	
53	ADSBTmeP	ADS-B Host Time Stamp, Seconds since UTC midnight	
54	ADSBVVIP	ADS-B Host Time Stamp, Seconds since OTC midnight ADS-B Host Vertical Velocity, ft/min (up is positive)	
55	ADSBAlt1	ADS-B Intruder 1 Altitude, pressure altitude ft	
56	ADSBLMR1	ADS-B Intruder 1 Data Message Missed, (TRUE = Data contained in	
30	, LOODLIVII (1	report is extrapolated	
		FALSE = Actual message contained in report)	
57	ADSBLat1	ADS-B Intruder 1 Latitude, WGS84 deg	

Field	Parameter	Description/Units
58	ADSBLng1	ADS-B Intruder 1 Longitude, WGS84 deg
59	ADSBTme1	ADS-B Intruder 1 Time Stamp, Seconds since UTC midnight
60	ADSBVVI1	ADS-B Intruder 1 Vertical Velocity, ft/min (up is positive)
61	ADSBAlt2	ADS-B Intruder 2 Altitude, pressure altitude ft
62	ADSBLMR2	ADS-B Intruder 2 Data Message Missed, (TRUE = Data contained in report is extrapolated FALSE = Actual message contained in report)
63	ADSBLat2	ADS-B Intruder 2 Latitude, WGS84 deg
64	ADSBLng2	ADS-B Intruder 2 Longitude, WGS84 deg
65	ADSBTme2	ADS-B Intruder 2 Time Stamp, Seconds since UTC midnight
66	ADSBVVI2	ADS-B Intruder 2 Vertical Velocity, ft/min (up is positive)
67	ADSBAlt3	ADS-B Intruder 3 Altitude, pressure altitude ft
68	ADSBLMR3	ADS-B Intruder 3 Data Message Missed, (TRUE = Data contained in report is extrapolated FALSE = Actual message contained in report)
69	ADSBLat3	ADS-B Intruder 3 Latitude, WGS84 deg
70	ADSBLng3	ADS-B Intruder 3 Longitude, WGS84 deg
71	ADSBTme3	ADS-B Intruder 3 Time Stamp, Seconds since UTC midnight
72	ADSBVVI3	ADS-B Intruder 3 Vertical Velocity, ft/min (up is positive)
73	VSI Command Counter	Counter incremented with each new GCS "VSI" command

Source: Scaled Composites data file, Flt369_A5_GCS_Channel_List.xls

Proteus GPS Parameter List

Field	Parameter	Units
1	GPS TIME	SEC
2	LATITUDE	DEG
3	LONGITUDE	DEG
4	ALTITUDE MSL	FT
5	VELOCITY NORTH	FT/SEC
6	VELOCITY EAST	FT/SEC
7	VELOCITY DOWN	FT/SEC

Source: Scaled Composites data files, fltXXX_raw_gps.txt (Where XXX is the Proteus flight number)

Common Tool Parameter List

Field	Parameter	FMS Cross Reference, where available
1	CTtime	
2	D6Time	
3	D6TFrame	
4	RTError	
5	RTPercent	
6	AltRef	
7	Lonstk_in	
8	LonstkTrm_in	
9	LonstkAP_in	
10	Latstk_in	
11	LatstkTrm_in	
12	LatstkAP_in	
13	Dir_in	
14	DirTrm_in	
15	DirAP_in	
16	APCmd	
17	AllAutopilot	
18	NzCommand	
19	DSixLatitude	
20	DSixLongitude	
21	NumIntruders	
22	DSixVehID	
23	WWIntruderID	
24	UseNetIntrData	
25	WWIntruderVt	
26	RelativeAltIC	
27	RelativelCsFlag	
28	RelativeRangeIC	
29	RelativeBearingIC	
30	RelativeVelocityIC	
31	RelativeHeadingIC	
32	UseRegurgatime	
33	UseGPSTime	
34	UseLocalTime	
35	Access5Time	
36	GPS_PPS	
37	GPSUTCsec	
38	GPSUTCmsec	
39	HOSTLat	

Field	Parameter	Description/Units
40	HOSTLong	
41	HOSTAIt	
42	HOSTVehID	
43	HOSTPsi	
44	AdsbOn	
45	CasLogicOn	
46	AaAllClear	
47	AaDescend	
48	AaClimb	
49	AaVerticalSpeed	
50	VSIptr	
51	RaAltRateGoal	
52	RaVerticalControl	
53	RaClimb	
54	RaDescend	
55	TcasRange5	
56	TcasRange10	
57	TcasRange20	
58	TcasRange40	
59	Intr1VehID	
60	Intr2VehID	
61	Intr3VehID	
62	Intr1Range	
63	Intr2Range	
64	Intr3Range	
65	Intr1Bearing	
66	Intr2Bearing	
67	Intr3Bearing	
68	Intr1RelAlt	
69	Intr2RelAlt	
70	Intr3RelAlt	
71	Intr1AdvisoryCode	
72	Intr2AdvisoryCode	
73	Intr3AdvisoryCode	
74	Intr1DisplayArrow	
75	Intr2DisplayArrow	
76	Intr3DisplayArrow	
77	Talpx1	
78	Talpx2	
79	Talpx3	
80	Talpy1	
81	Talpy2	
82	Talpy3	

Field	Parameter	Description/Units
83	Talpz1	
84	Talpz2	
85	Talpz3	
86	TaSqU1Vis	
87	TaSqU2Vis	
88	TaSqU3Vis	
89	TaSqD1Vis	
90	TaSqD2Vis	
91	TaSqD3Vis	
92	TaSqN1Vis	
93	TaSqN2Vis	
94	TaSqN3Vis	
95	TaUDiaU1Vis	
96	TaUDiaU2Vis	
97	TaUDiaU3Vis	
98	TaUDiaD1Vis	
99	TaUDiaD2Vis	
100	TaUDiaD3Vis	
101	TaUDiaN1Vis	
102	TaUDiaN2Vis	
103	TaUDiaN3Vis	
104	TaUDiaNN1Vis	
105	TaUDiaNN2Vis	
106	TaUDiaNN3Vis	
107	TaSqNN1Vis	
108	TaSqNN2Vis	
109	TaSqNN3Vis	
110	TaTrN1Vis	
111	TaTrN2Vis	
112	TaTrN3Vis	
113	UseUDP	
114	OriginID	
115	TcasDisplayRange	
116	CTVersionID	
117	CmdlpAddress1	
118	CmdlpAddress2	
119	CmdlpAddress3	
120	CmdlpAddress4	
121	CmdlpPort	
122	TaHdg1	
123	TaHdg2	
124	TaHdg3	

Field	Parameter	Description/Units
125	UseDirectionPtr	
126	SideslipOn	
127	OwnshipRotateAngl	
128	RaIncDiveArcOn	
129	RalncClimbArcOn	
130	CmdAircraftID	
131	CmdAirspeed	Host Airspeed
132	CmdAltitude	Host Altitude
133	CmdCommandID	GCS CommandID
134	CmdHeading	Host Heading
135	CmdRateOfClimb	Host Rate_of_Climb
136	DoAutoManeuver	
137	AaClimbCross	
138	AaDescendCross	
139	RaLimitClimbArcOn	
140	RaLimitDiveArcOn	
141	RaGreenArcOn	
142	HOSTRoc	
143	RaTimeBufferSec	CAS Algorithm Buffer Setting
144	RaCombControl	
145	ClimbRatefpm	
146	HOSTSource	
147	AdsbHostAcNum	ADS-B Host Vehicle ID
148	AdsbHostTime	ADS-B Host Time Stamp
149	AdsbHostDataMiss	ADS-B Host Data Message Missed
150	AdsbHostLat	ADS-B Host Latitude
151	AdsbHostLong	ADS-B Host Longitude
152	AdsbHostAlt	ADS-B Host Altitude
153	AdsbHostVertVel	ADS-B Host Vertical Velocity
154	AdsbIntr1AcNum	ADS-B Intruder 1 Vehicle ID
155	AdsbIntr2AcNum	ADS-B Intruder 2 Vehicle ID
156	AdsbIntr3AcNum	ADS-B Intruder 3 Vehicle ID
157	AdsbIntr1Time	ADS-B Intruder 1 Time Stamp
158	AdsbIntr2Time	ADS-B Intruder 2 Time Stamp
159	AdsbIntr3Time	ADS-B Intruder 3 Time Stamp
160	AdsbIntr1DataMiss	ADS-B Intruder 1 Data Message Missed
161	AdsbIntr2DataMiss	ADS-B Intruder 2 Data Message Missed
162	AdsbIntr3DataMiss	ADS-B Intruder 3 Data Message Missed
163	AdsbIntr1Lat	ADS-B Intruder 1 Latitude
164	AdsbIntr2Lat	ADS-B Intruder 2 Latitude
165	AdsbIntr3Lat	ADS-B Intruder 3 Latitude
166	AdsbIntr1Long	ADS-B Intruder 1 Longitude
167	AdsbIntr2Long	ADS-B Intruder 2 Longitude

Field	Parameter	Description/Units	
168	AdsbIntr3Long	ADS-B Intruder 3 Longitude	
169	AdsbIntr1Alt	ADS-B Intruder 1 Altitude	
170	AdsbIntr2Alt	ADS-B Intruder 2 Altitude	
171	AdsbIntr3Alt	ADS-B Intruder 3 Altitude	
172	AdsbIntr1VertVel	ADS-B Intruder 1 Vertical Velocity	
173	AdsbIntr2VertVel	ADS-B Intruder 2 Vertical Velocity	
174	AdsbIntr3VertVel	ADS-B Intruder 3 Vertical Velocity	
175	AdsbNumIntruders	ADS-B Number of Intruders	
176	TcasIntr1AcNum	Host TCAS Intruder 1 ID	
177	TcasIntr2AcNum	Host TCAS Intruder 2 ID	
178	TcasIntr3AcNum	Host TCAS Intruder 3 ID	
179	TcasIntr1Time	Host TCAS Intruder 1 Timestamp	
180	TcasIntr2Time	Host TCAS Intruder 2 Timestamp	
181	TcasIntr3Time	Host TCAS Intruder 3 Timestamp	
182	TcasIntr1Range	Host TCAS Intruder 1 Relative Range	
183	TcasIntr2Range	Host TCAS Intruder 2 Relative Range	
184	TcasIntr3Range	Host TCAS Intruder 3 Relative Range	
185	TcasIntr1Bearing	Host TCAS Intruder 1 Relative Bearing	
186	TcasIntr2Bearing	Host TCAS Intruder 2 Relative Bearing	
187	TcasIntr3Bearing	Host TCAS Intruder 3 Relative Bearing	
188	TcasIntr1RelAlt	Host TCAS Intruder 1 Relative Altitude	
189	TcasIntr2RelAlt	Host TCAS Intruder 2 Relative Altitude	
190	TcasIntr3RelAlt	Host TCAS Intruder 3 Relative Altitude	
191	TcasIntr1DispArrow	Host TCAS Intruder 1 Display Arrow	
192	TcasIntr2DispArrow	Host TCAS Intruder 2 Display Arrow	
193	TcasIntr3DispArrow	Host TCAS Intruder 3 Display Arrow	
194	TcasIntr1AdvCode	Host TCAS Intruder 1 Advisory Code	
195	TcasIntr2AdvCode	Host TCAS Intruder 2 Advisory Code	
196	TcasIntr3AdvCode	Host TCAS Intruder 3 Advisory Code	
197	TcasIntr1DataStat	Host TCAS Intruder 1 Data Status	
198	TcasIntr2DataStat	Host TCAS Intruder 2 Data Status	
199	TcasIntr3DataStat	Host TCAS Intruder 3 Data Status	
200	TcasNumIntruders	Host TCAS Number of Intruders	
201	TcasSourceCas	Host TCAS Source CAS	
202	OwnshipAircraftID	Host Nav Vehicle ID	
203	OwnshipTime	Host Nav Timestamp	
204	OwnshipLat	Host Nav Sensed Latitude	
205	OwnshipLong	Host Nav Sensed Longitude	
206	OwnshipAlt	Host Nav Sensed Altitude	
207	OwnshipVelNorth	Host Nav Sensed Velocity North	
208	OwnshipVelEast	Host Nav Sensed Velocity East	
209	OwnshipVertVel	Host Nav Sensed Vertical Velocity	
210	OwnshipEulerRoll	Host Nav Sensed Roll Angle	

Field	Parameter	Description/Units
211	OwnshipEulerPitch	Host Nav Sensed Pitch Angle
212	OwnshipTrueHead	Host Nav Sensed Heading
213	TcasRaClimb	Host TCAS RA Climb
214	TcasRaDescend	Host TCAS RA Descend
215	TcasRaAltRate	Host TCAS RA Altitude Rate Goal
216	TcasRaVertCtrl	Host TCAS RA Vertical Control
217	TcasRaCombCtrl	Host TCAS RA Combined Control
218	MinimumSeparation	
219	CmdTime	Host Time
220	RaDelay	
221	RaDelayCount	
222	RaMaxVertfpm	CAS Algorithm Climb Limit Setting
223	GroundCasReset	
224	FltTst3dDisp	

Source: Lockheed Martin data file, DSixVariables_tracebility_to_CCAPL.xls

G-III Parameter List

Field	Parameter Parameter
1	0000XXadc1_ias
2	0000XXadc1 palt
3	0000XXadc1 tas
4	0000XXadc1_tat
5	0000XXadc1 vert spd
6	0000XXadc2 ias
7	0000XXadc2 palt
8	0000XXadc2 tas
9	0000XXadc2 tat
10	0000XXadc2_vert_spd
11	0000XXday
12	0000XXday_of_year
13	0000XXfms1_grnd_spd
14	0000XXfms1 lat
15	0000XXfms1 lon
16	0000XXfms1 pres alt
17	0000XXfms1 true hdg
18	0000XXfms2 grnd spd
19	0000XXfms2 lat
20	0000XXfms2 lon
21	0000XXfms2_pres_alt
22	0000XXfms2_true_hdg
23	0000XXfms2_trk_ang
24	0000XXgps1_alt_msl
25	0000XXgps1_lat
26	0000XXgps1_lat_fine
27	0000XXgps1_lon
28	0000XXgps1_lon_fine
29	0000XXgps1_trk_ang
30	0000XXgps1_vert_spd
31	0000XXgps2_alt_msl
32	0000XXgps2_lat
33	0000XXgps2_lat_fine
34	0000XXgps2_lon
35	0000XXgps2_lon_fine
36	0000XXgps2_trk_ang
37	0000XXgps2_vert_spd
38	0000XXins1_body_lat_accel
39	0000XXins1_body_lon_accel
40	0000XXins1_body_normal_accel
41	0000XXins1_e_w_velocity
42	0000XXins1_grnd_spd
43	0000XXins1_inert_vert_spd
44	0000XXins1_inertial_alt

45 0000XXins1_n_s_velocity		
46 0000XXins1_pitch_ang		
47 0000XXins1_platform_hdg		
48 0000XXins1_roll_ang		
49 0000XXins1_vertical_accel		
50 0000XXins2_body_lat_accel		
51 0000XXins2_body_lon_accel		
52 0000XXins2_body_normal_accel		
53 0000XXins2_e_w_velocity		
54 0000XXins2_grnd_spd		
55 0000XXins2_inert_vert_spd		
56 0000XXins2_inertial_alt		
57 0000XXins2_n_s_velocity		
58 0000XXins2_pitch_ang		
59 0000XXins2_platform_hdg		
60 0000XXins2_roll_ang		
61 0000XXins2_vertical_accel		
62 0000XXmonth		
63 0000XXmp_xacc		
64 0000XXmp_yacc		
65 0000XXmp_zacc		
66 0000XXtime_in_hrs		
67 0000XXtime_in_msec		
68 0000XXtime_in_secs		
69 0000XXyear		
70 0000XXzxt_alt_meter		
71 0000XXzxt_lat		
72 0000XXzxt_lon		
Where 'XX' is the G-III flight number (23,24,25,27,28)		

Source: NASA G-III data files

Appendix C – Processed Data Structures

The data collected during the CCA flight Demonstration was obtained from 4 sources, GIII Instrumentation, Proteus FMS, Ground Control Station, and Common Tool. The two aircraft sources contained more parameters than were actually necessary to determine a 'truth' position for the aircraft and sensor performance.

For the GIII intruder, several position parameters were evaluated to determine which one of the sources provided the most reliable and accurate measurement of latitude and longitude of the aircraft. Although the ZXT source was expected to be more accurate, it was not available for all runs. The GPS1 source had the best availability and was selected to provide the GIII 'truth' source.

The Proteus FMS data had GPS and INS position data sources. The GPS data, however, was not accurate and the INS source was initially selected even though it was a blended solution with possible position errors that were not well understood because of the proprietary CMIGITS II hardware. A subsequent release of the raw GPS data from Scaled Composites resulted in a better GPS source and it was then selected to provide the 'truth' position data. Since it was desirable to have both position sources from the same type of equipment, this data proved to be an important source. Data is stored for the runs beginning at the time the autopilot was engaged and the ground pilot took control until aircraft control was returned to the aircraft.

The ADS-B information was collected by the Proteus FMS. GPS position data from a separate source that was part of the ADS-B hardware was available for both the host and intruder. Although up to three intruders could be tracked, the GIII data was consistently found in the Intruder 1 position.

The TCAS information was also collected by the Proteus FMS. TCAS data is in the form of a range and bearing that will be compared to range and bearing values calculated from the 'truth' position data. As with the ADS-B, there are up to three tracks of TCAS data available but due to implementation on the Proteus and the presence of other aircraft in the area with TCAS equipment, the GIII data tended to change from one track to the other and sometimes was not available because three other aircraft were recorded. This complicated processing of the TCAS data and in some cases made it impossible to determine TCAS range and bearing data for portions of a run.

The GCS data contains much of the same data recorded on the Proteus aircraft. Data latencies can be determined by observing the difference in time that the data was recorded on the aircraft and when it was recorded in the GCS. Unfortunately, it appears that the time data in the GCS is not accurate enough (integer seconds only) to make the necessary comparisons. Additionally, the GCS data was to be used as the source of the time of the pilot input when responding to a RA. This data does not appear to be available at this time. Scaled Composites is reviewing the data at this time.

The Common Tool data provides another measure of the collision avoidance timeline by indicating the time that the RA was displayed to the ground pilot. Data is stored for the runtimes determined by the autopilot engagement times.

Only data for Proteus Flights 369, 370, 374, and 375 and associated GCS, Common Tool, and GIII flights have been processed. Flight 368 Proteus FMS data did not include an INS Time parameter to provide UTC timing for the data. The run numbers in the database match the Scribe Notes runs except for Flight 369. Cycling of the autopilot during Run 8 resulted in that run being identified as Runs 8, 9, 10. Since that run was not selected for additional analysis due to system problems during the run, the error in run numbers was not corrected. Subsequent runs on that flight are numbered incorrectly. Due to a processing error, the data for the last four runs on the last flight were not included in the data submitted by Scaled Composites.

All data has been interpolated as required or discrete values selected for UTC times at xx.0 and xx.5 in order to make comparisons of the data across multiple sources.

Queries in each of the databases listed below were developed during data processing to verify that the processes were functioning properly. In some case, the queries may no longer work as tables and table structures may have been modified.

Flight Demo GCS v1.mdb		
Table	Contents	
GCS_Run_Data	Records for all runs from autopilot engage to disengage for the four processed flights. Fields have been added for flight and run numbers and to translate the G16 timing used in the GCS to UTC time.	
RawGCSData_369	All raw data from the Scaled Composites data file for Flight 369	
RawGCSData_370	All raw data from the Scaled Composites data file for Flight 369	
RawGCSData_374	All raw data from the Scaled Composites data file for Flight 369	
RawGCSData_375	All raw data from the Scaled Composites data file for Flight 369	

Flight Demo GIII v2.mdb		
Table	Contents	
000024GIII_Data_v1	Selected raw data from the NASA data file for Flight 24 flown	
	during Proteus Flight 369. Fields have been added for Flight,	
	Run, and Time ID's.	
000025GIII_Data_v1	Selected raw data from the NASA data file for Flight 24 flown	
	during Proteus Flight 370. Fields have been added for Flight,	
	Run, and Time ID's.	
000027GIII_Data_v1	Selected raw data from the NASA data file for Flight 24 flown	
	during Proteus Flight 374. Fields have been added for Flight,	
	Run, and Time ID's.	
000028GIII_Data_v1	Selected raw data from the NASA data file for Flight 24 flown	
_	during Proteus Flight 375. Fields have been added for Flight,	

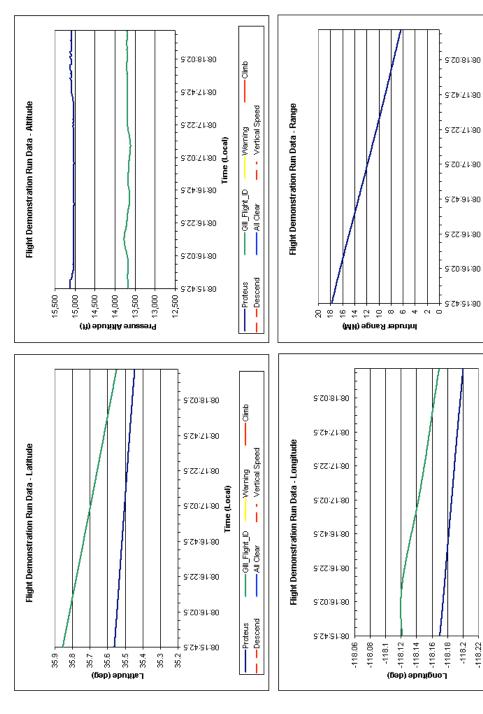
	Run, and Time ID's.	
Adjusted GIII All	GPS Leading Edge data interpolated to xx.0 and xx.5	
APEngage	Autopilot engage and disengage times for each of the runs. Also provides a cross reference for the Proteus and GIII flight numbers	
GIII_Parameters	Listing of the GIII parameters selected for upload to the database.	
Leading_Edge_GIII_All	dge_GIII_All Selected records for the leading edge of all GPS data update processed from the raw data.	
Run_Count	Listing of the number of runs during each flight used for data processing tools developed to import Scaled Composites and NASA data files.	
Version	Version control information indicating changes and additions.	

Flight Demo Proteus v2.mdb		
Table	Contents	
Adjusted_GPS_Data	GPS leading edge data interpolated to xx.0 and xx.5	
Adjusted_Proteus_All	INS and other parameters interpolated to xx.0 and xx.5. Data	
	was extracted for INS leading edge and interpolated before raw	
	GPS data was available.	
APEngage	Autopilot engage and disengage times for each of the runs. Also	
	provides a cross reference for the Proteus and GIII flight	
	numbers	
FMS_Channels	Listing of the Proteus FMS parameters selected for upload to the	
	database.	
FMS_Data	Selected parameters of the raw FMS data for each of the runs	
	from autopilot engage to disengage. INS leading edge data was	
	selected from these records	
Raw_GPS_Data	Raw GPS data extracted for each run from autopilot engage to	
	disengage. Flight and Run ID's added as well as GPS timing	
	translated to UTC.	
Run_Count	Listing of the number of runs during each flight used for data	
	processing tools developed to import Scaled Composites and	
	NASA data files.	

Flight Demo Pseudo TSPI v6.mdb			
This database contains tables imported	This database contains tables imported from the GPS, Proteus, and GIII databases to be used		
during analysis. It contains queries that simplify the process of matching the time stamps for t			
data.			
Table	Contents		
Adjusted_ADSB_Leading_Edge	ADS-B leading edge data interpolated to xx.0 and xx.5.		
	Continuous parameters are interpolated as required and		
	discreet values are for the later point used in the		
	interpolation.		

Adjusted_GIII_All	GPS Leading Edge data interpolated to xx.0 and xx.5
	(duplicate data)
Adjusted_GPS_Data	GPS leading edge data interpolated to xx.0 and xx.5
	(duplicate data)
Adjusted_Proteus_All	INS and other parameters interpolated to xx.0 and xx.5.
	Data was extracted for INS leading edge and
	interpolated before raw GPS data was available.
	(duplicate data)
Adjusted_TCAS_GIII_Leading_Edge	TCAS leading edge data interpolated to xx.0 and xx.5.
	Continuous parameters are interpolated as required and
	discreet values are for the later point used in the
	interpolation.
APEngage	Autopilot engage and disengage times for each of the
	runs. Also provides a cross reference for the Proteus and
	GIII flight numbers
Version	Version control information indicating changes and
	additions.

Flight_Demo_Common_Tool v1.mdb	
Table	Contents
APEngage	Autopilot engage and disengage times for each of the runs. Also provides a cross reference for the Proteus and GIII flight numbers and the associated Lockheed Martin filenames for the Common Tool data where available.
CommonTool_Flt_Demo_Data_369	Raw Common Tool data from autopilot engage to disengage collected from Proteus Flight 369. Some runs did not have an associated file with data available.
CommonTool_Flt_Demo_Data_370	Raw Common Tool data from autopilot engage to disengage collected from Proteus Flight 369. Some runs did not have an associated file with data available.
CommonTool_Flt_Demo_Data_374	Raw Common Tool data from autopilot engage to disengage collected from Proteus Flight 369. Some runs did not have an associated file with data available.
CommonTool_Flt_Demo_Data_375	Raw Common Tool data from autopilot engage to disengage collected from Proteus Flight 369. Some runs did not have an associated file with data available.



Flight 369 - Run 1 (3.03, Co-Heading, Intruder Climbing, TRT, 0/0, Climb Inhibit)

Warning ——All Clear

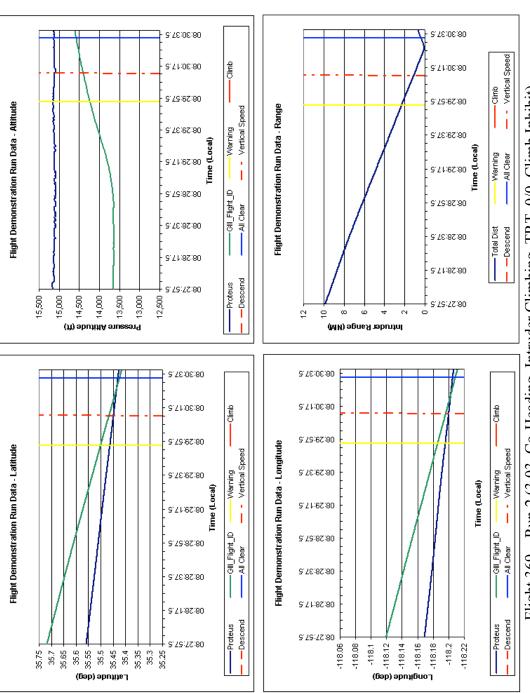
Total Dist
Descend

Ojii Ojii Ojii

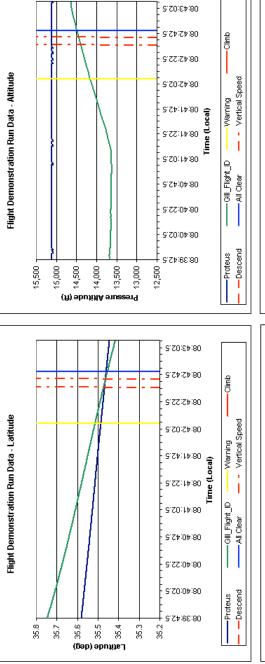
Warning — Vertical Speed

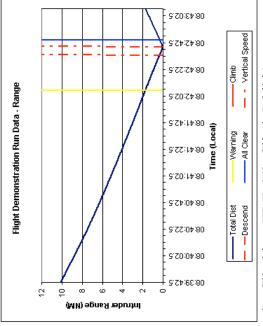
-118.22

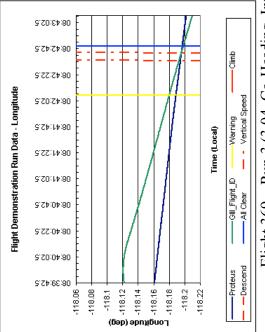
Time (Local)



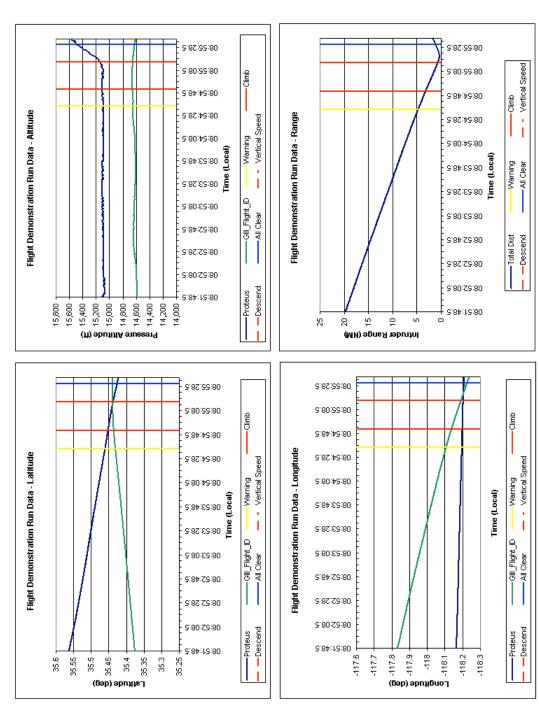
Flight 369 - Run 2 (3.03, Co-Heading, Intruder Climbing, TRT, 0/0, Climb Inhibit)



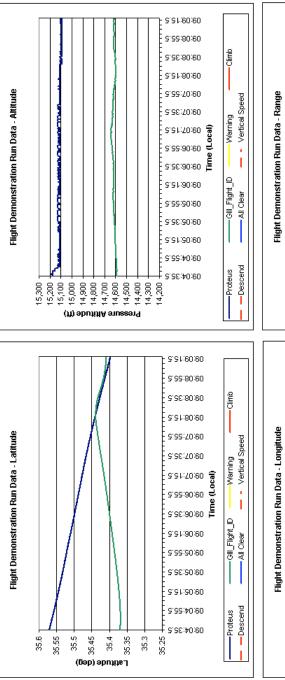


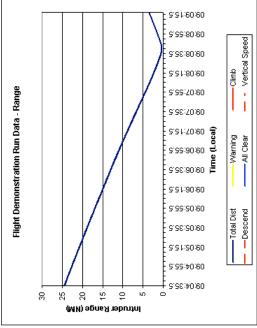


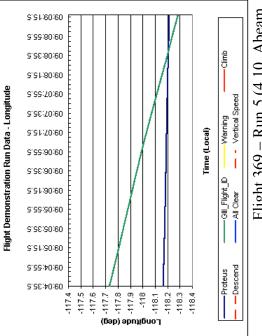
Flight 369 - Run 3 (3.04, Co-Heading, Intruder Climbing, TRT, 0/0, Climb Inhibit)



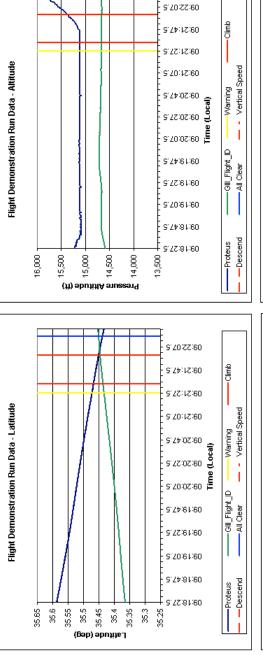
Flight 369 – Run 4 (4.09, Abeam, Co-Altitude, AGA, 2/0, 2500 fpm)

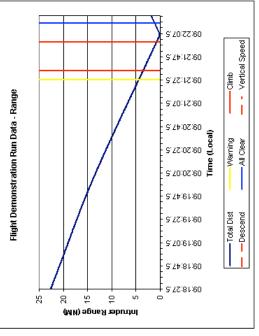


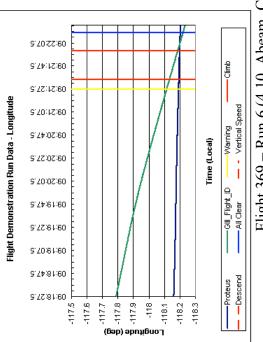




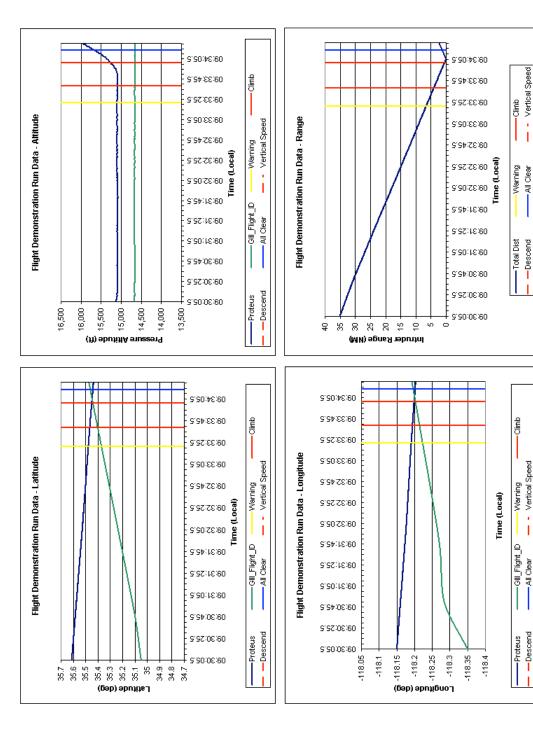
Flight 369 – Run 5 (4.10, Abeam, Co-Altitude, AGA, 0/0, 2500 fpm)







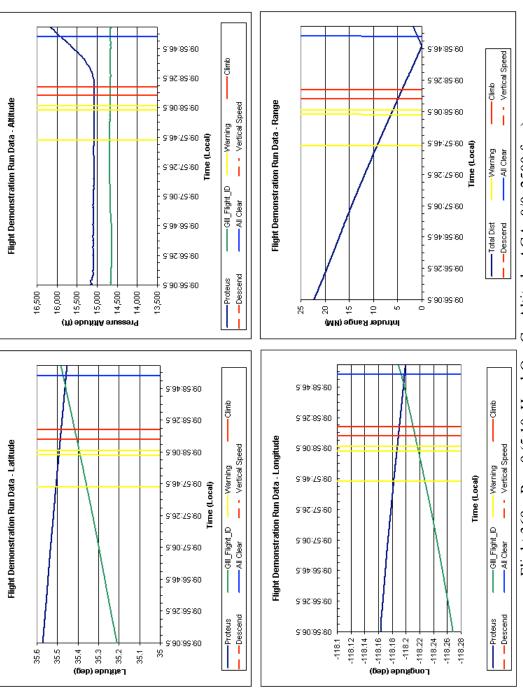
Flight 369 - Run 6 (4.10, Abeam, Co-Altitude, AGA, 0/0, 2500 fpm)



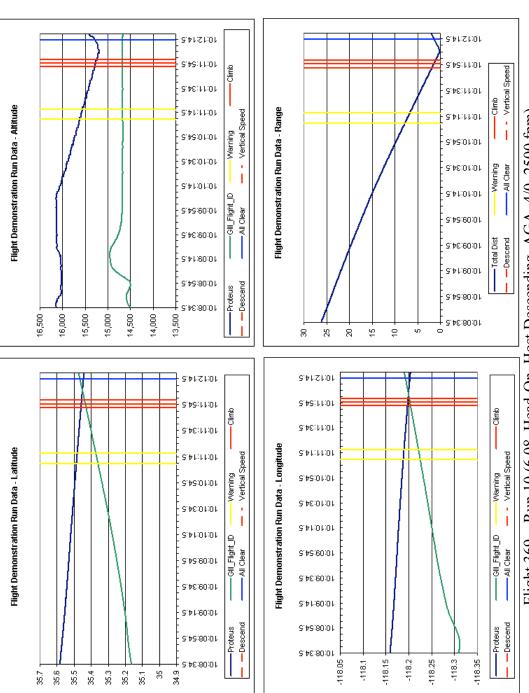
Flight 369 - Run 7 (5.09, Head-On, Co-Altitude, AGA, 2/0, 2500 fpm)

No Data Available

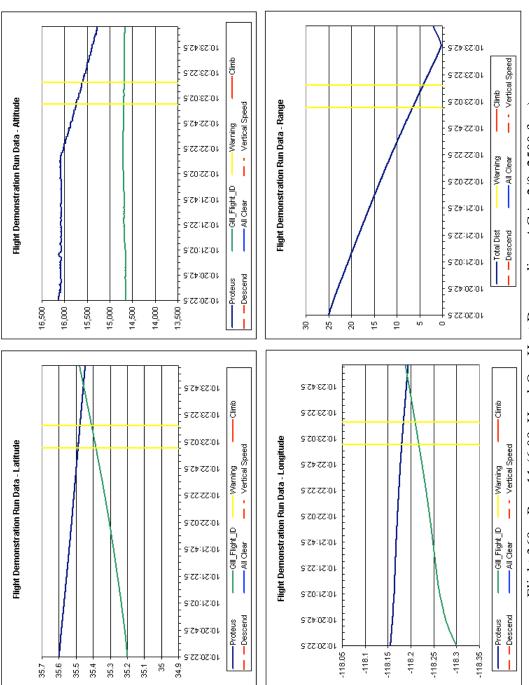
Flight 369 - Run 8 (5.10, Head-On, Co-Altitude, AGA, 0/0, 2500 fpm)



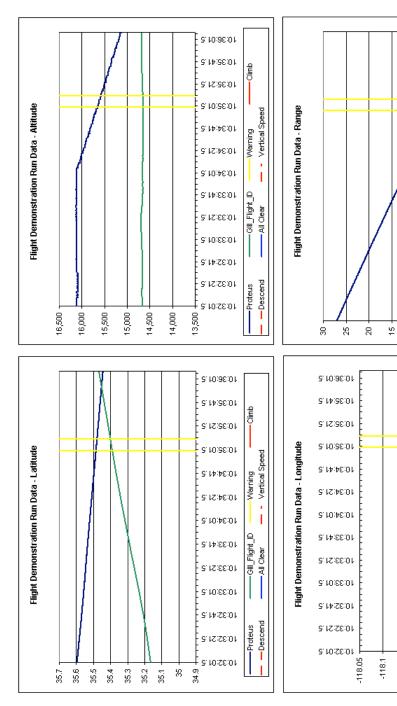
Flight 369 - Run 9 (5.10, Head-On, Co-Altitude, AGA, 0/0, 2500 fpm)



Flight 369 - Run 10 (6.08, Head-On, Host Descending, AGA, 4/0, 2500 fpm)



Flight 369 - Run 11 (6.09, Head-On, Host Descending, AGA, 2/0, 2500 fpm)



Flight 369 - Run 12 (6.10, Head-On, Host Descending, AGA, 0/0, 2500 fpm)

3,10:36:01

10:38:21.5

3,10:36:01

3,14:48:01

10:34:21.5

10:34:01.5

10:33:21.5

3,10:88:01

3,14:28:01

10:32:21.5

10:32:01 E

9

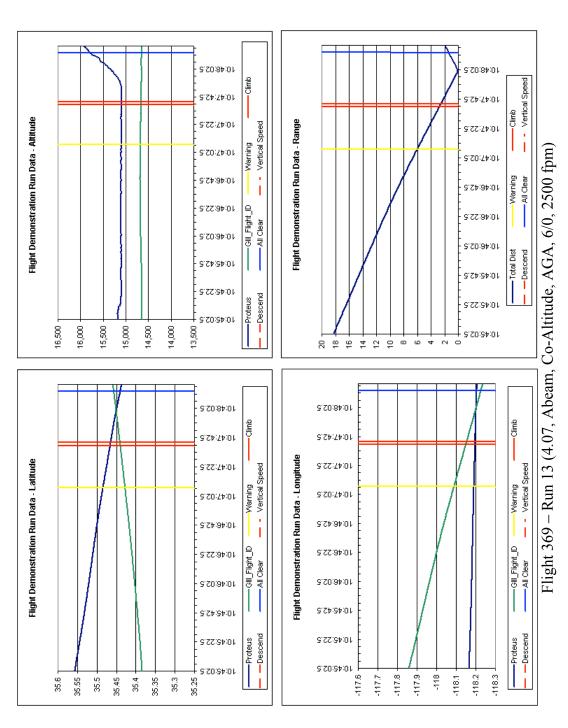
-118.15

-118.2

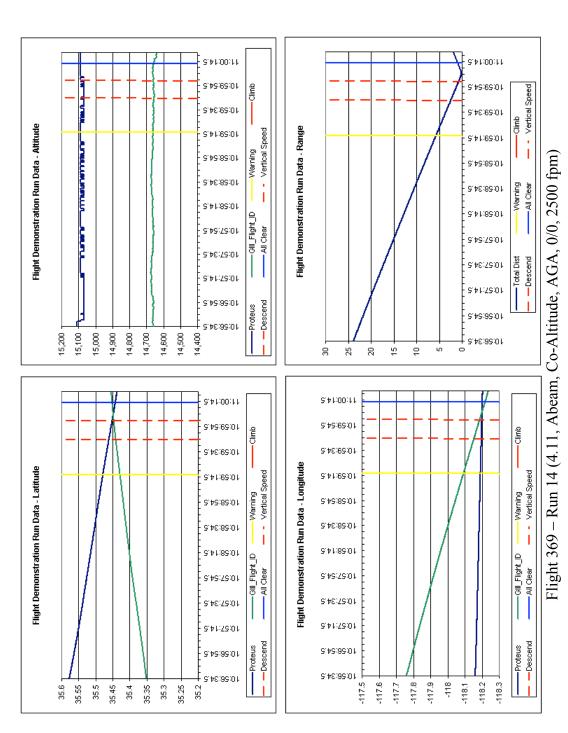
-118.25 --118.35 - Climb
- Vertical Speed

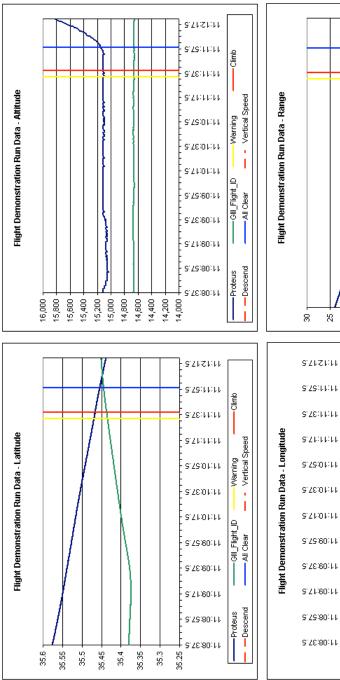
-Descend

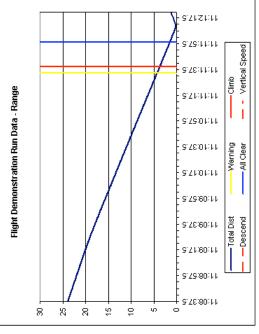
-Climb



Appendix D-13







Flight 369 - Run 15 (4.12, Abeam, Co-Altitude, AGA, 4/2, 2500 fpm)

-Cimb

- Warning -- Vertical Speed

-118.2 -

-118.1

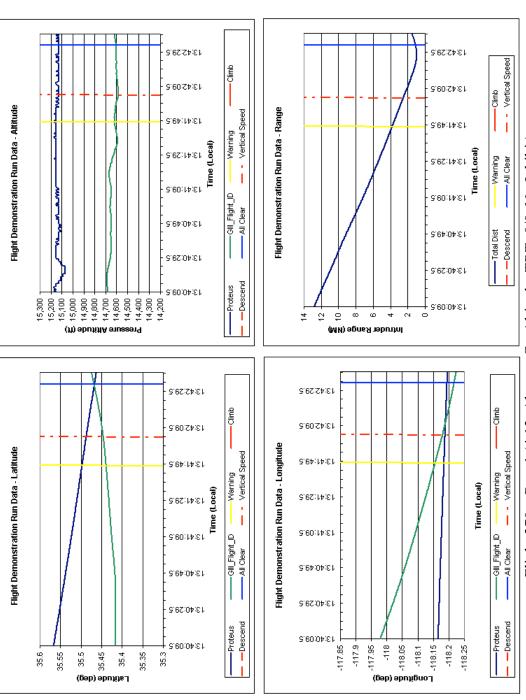
-118.3 -

-117.5 -

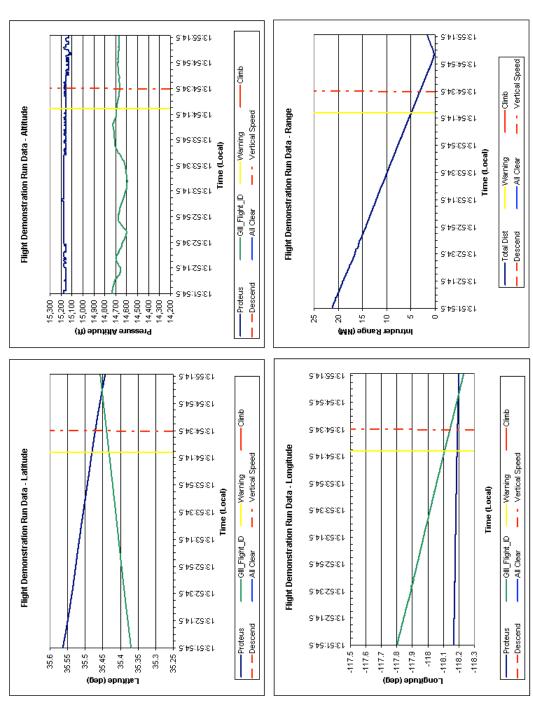
-117.4

-117.8 -

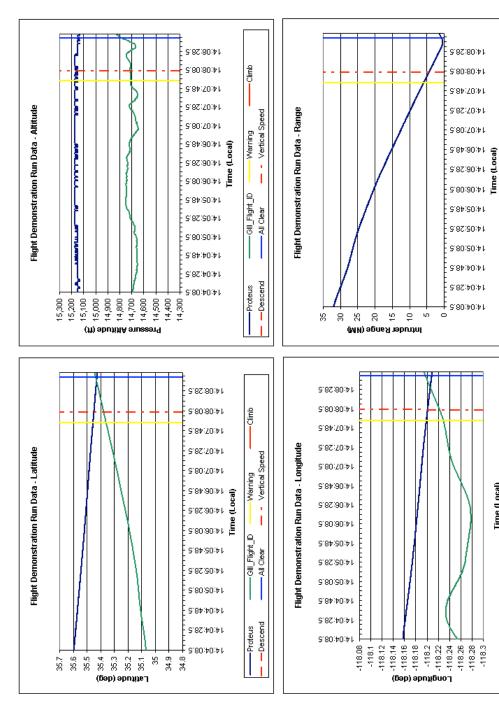
-117.7



Flight 370 - Run 1 (4.13, Abeam, Co-Altitude, TRT, 0/0, No Inhibit)



Flight 370 - Run 2 (4.14, Abeam, Co-Altitude, TRT, 0/2, No Inhibit)



Flight 370 - Run 3 (5.13, Head-On, Co-Altitude, TRT, 0/0, No Inhibit)

-Climb Vertical Speed

Warning - All Clear

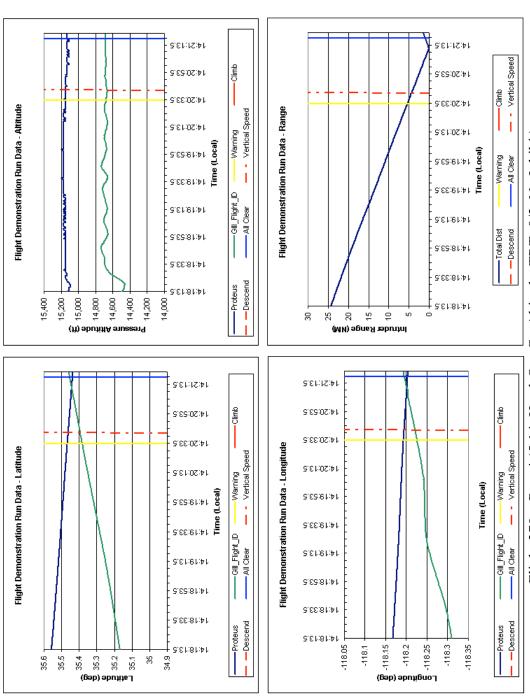
Total Dist
Descend

Climb

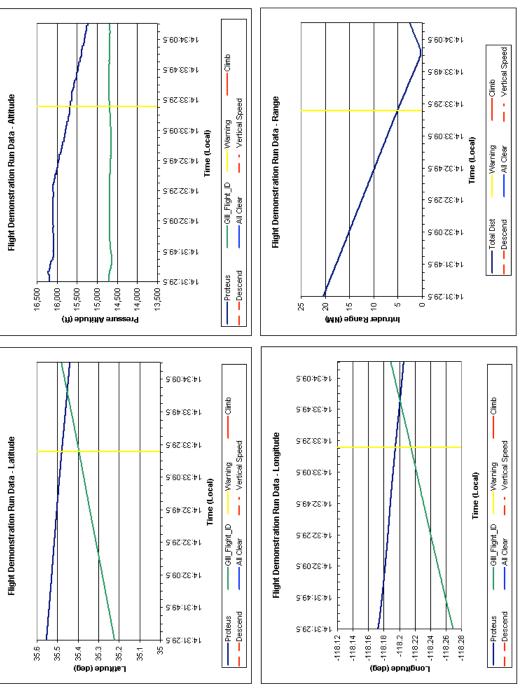
— GIII_Flight_ID — All Clear

-Proteus -Descend

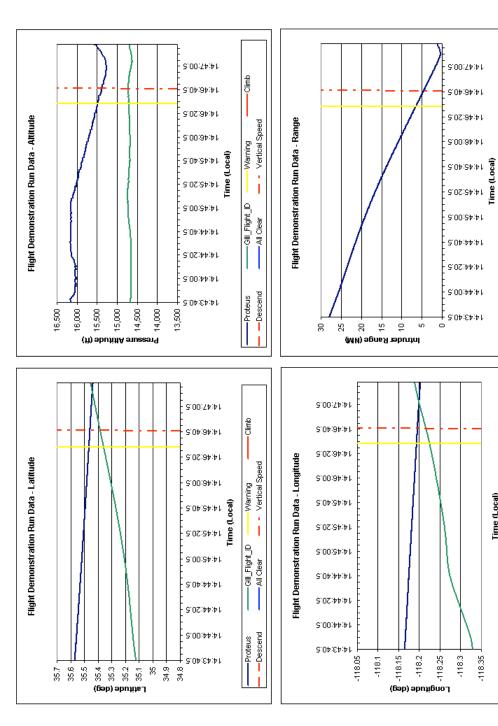
Time (Local)



Flight 370 - Run 4 (5.14, Head-On, Co-Altitude, TRT, 0/2, No Inhibit)



Flight 370 – Run 5 (6.13, Head-On, Host Descending, TRT, 0/0, No Inhibit)



Flight 370 – Run 6 (6.13, Head-On, Host Descending, TRT, 0/0, No Inhibit)

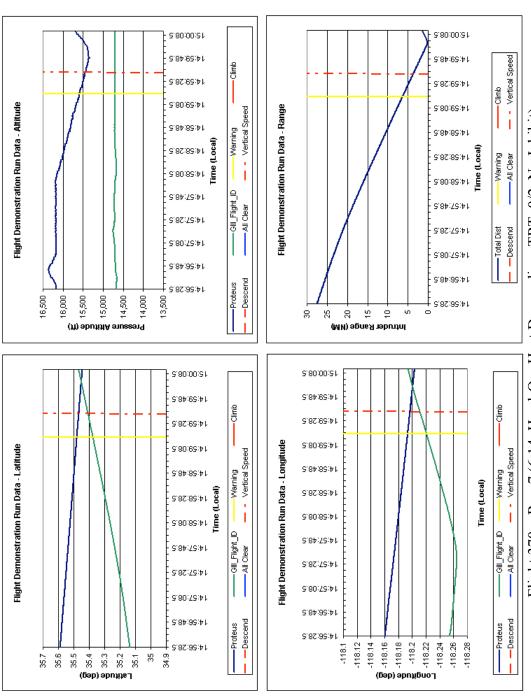
-Warning -All Clear

Total Dist
Descend

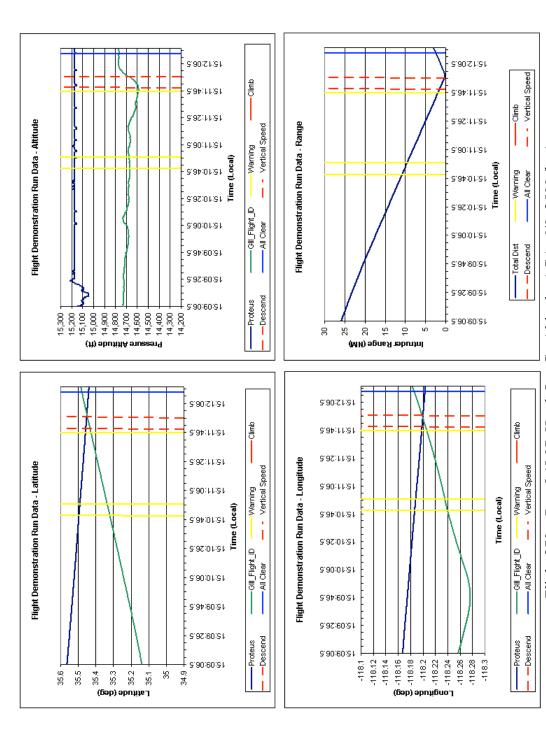
-Climb

Warning - Vertical Speed

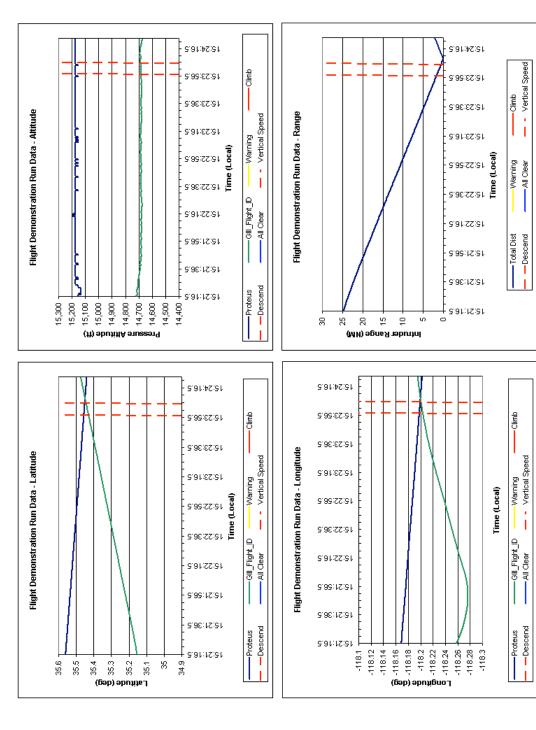
Time (Local)



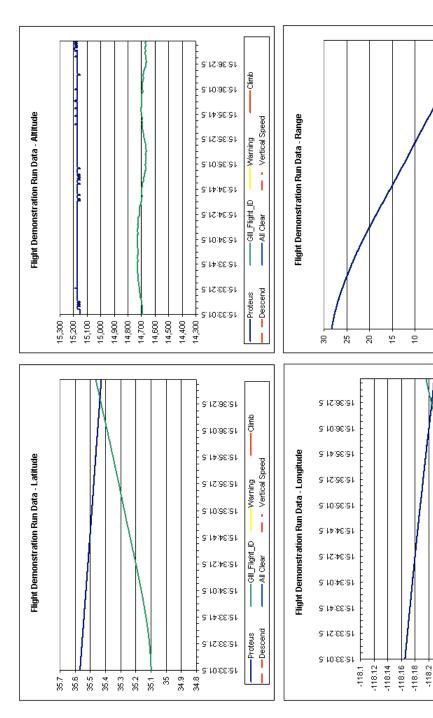
Flight 370 - Run 7 (6.14, Head-On, Host Descending, TRT, 0/2, No Inhibit)



Flight 370 - Run 8 (5.07, Head-On, Co-Altitude, AGA, 6/0, 2500 fpm)



Flight 370 - Run 9 (5.11, Head-On, Co-Altitude, AGA, 0/0, 2500 fpm)



Flight 370 - Run 10 (5.12, Head-On, Co-Altitude, AGA, 4/2, 2500 fpm)

9112:98:91

3,10:38:31

12:32:41.5

18:38:21.5

911039831

9114:48:91

18:34:21.5

8,14,88,81 8,10,48,81

15:33:21.5

18:33:01.8

w

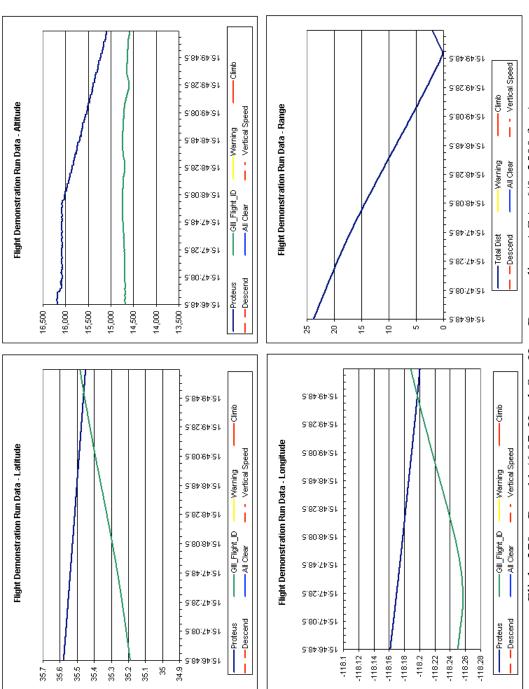
Climb
- Vertical Speed

Total Dist
Descend

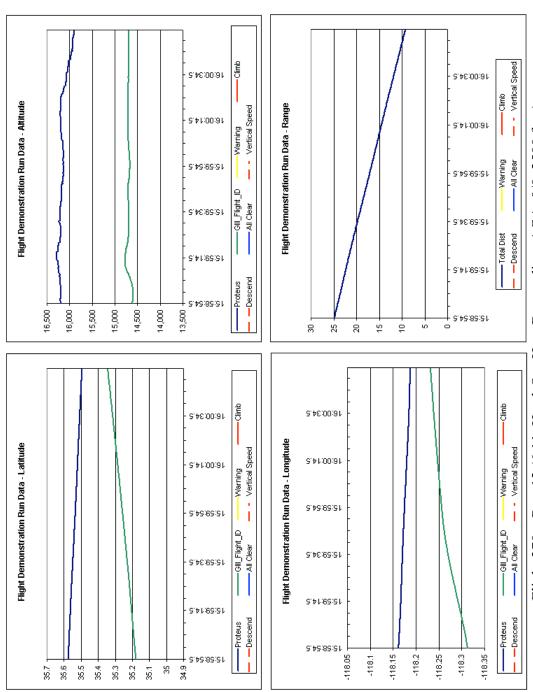
-Cimb

-118.22

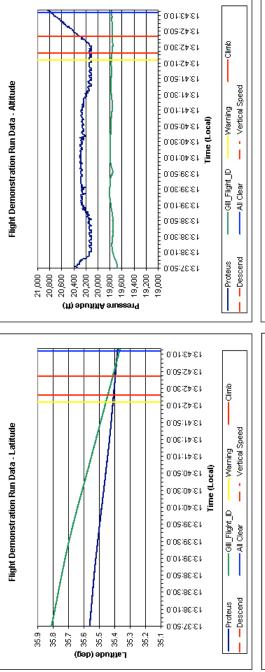
-118.26 -118.28 -118.3

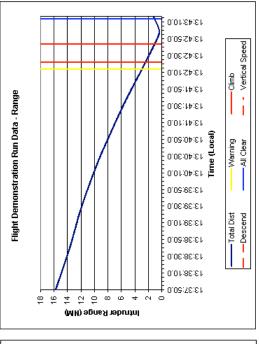


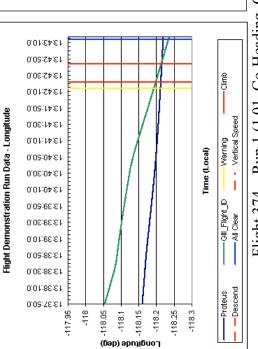
Flight 370 – Run 11 (6.07, Head-On, Host Descending, AGA, 6/0, 2500 fpm)



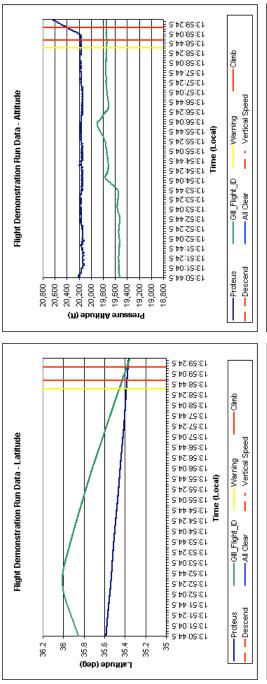
Flight 370 – Run 12 (6.11, Head-On, Host Descending, AGA, 0/0, 2500 fpm)

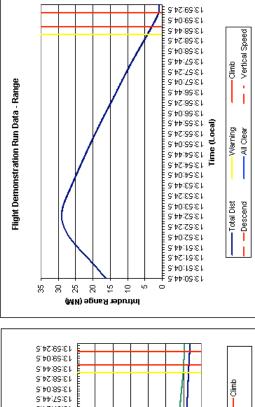






Flight 374 - Run 1 (1.01, Co-Heading, Co-Altitude, TGC, 0/0, 1000 fpm)





13:57:24.5

13:57:04.5

13:55:24:5 13:55:44:5 13:55:44:5 13:55:44:5

13:55:04:5

9144:49:81

13:54:24:5

13:52:44.5 13:53:04.5 13:53:04.5 13:54:04.5 13:54:04.5

13:25:54:2

13:52:04.5

13:51:44:5

13:51:24:5

3.40:18:51 8.40:18:51

-117.9

-117.95

-118

-118.05

light Demonstration Run Data - Longitude

Flight 374 – Run 2 (2.01, Low-Aspect, Co-Altitude, TGC, 0/0, 1000 fpm) climb -GII_Flight_ID -All Clear -Proteus -Descend

Time (Local)

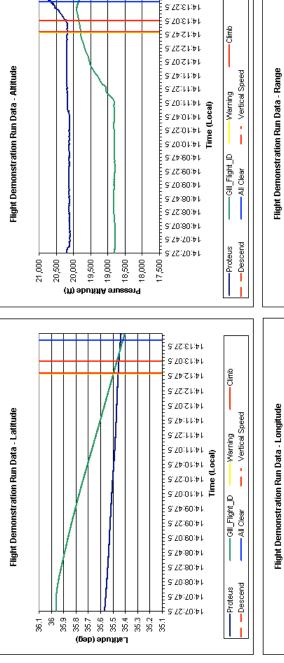
-118.15 -

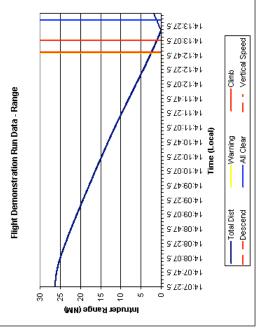
-118.1

Longitude (deg)

-118.25

Appendix D-29





14:13:27:5

9720/21/01

14:15:42:2

9,72,21,41 14,12,07,5

912411141

14:11:27.5

9120111701

5,70:01:41 8,72:01:41

9174:60:41

3,72;80;41

91Z03603#1

3,74:80:41

3,72;80;41

91Z0:80:#1

9124120141

14:07:27.5

-117.75 --117.8 --117.85 -

Longitude (deg)
-117.95
-118.05
-118.11

-118.15 --118.2 -

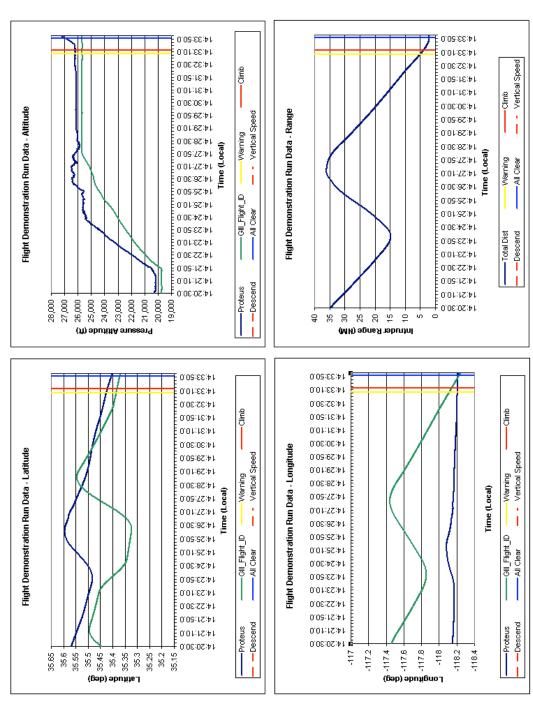
Flight 374 - Run 3 (3.01, Co-Heading, Intruder Climbing, TGC, 0/0, 1000 fpm)

Cimb

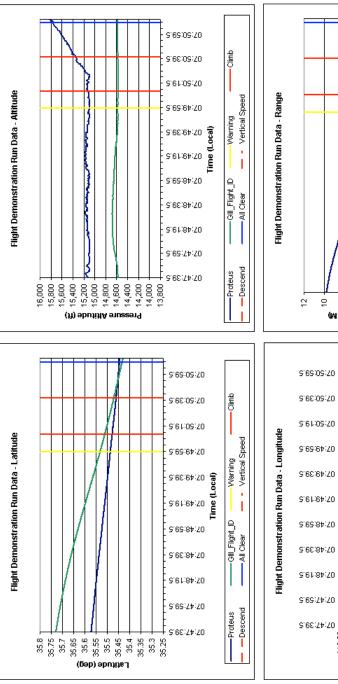
- Vertical Speed

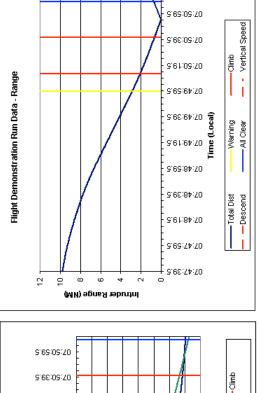
—GIII_Flight_ID —All Clear

Time (Local)



Flight 374 – Run 4 (4.02, Abeam, Co-Altitude, TGC, 4/0, 2500 fpm)





Longitude (deg)

-118.18 -118.2 -118.22

-118.08

-118.06

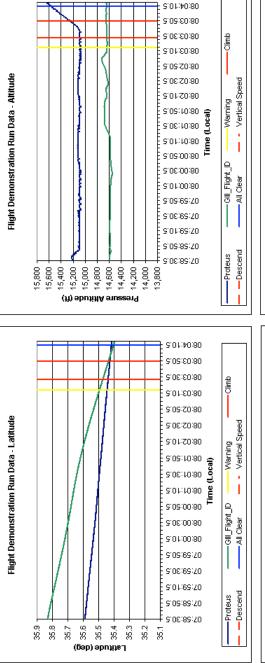
-118.1

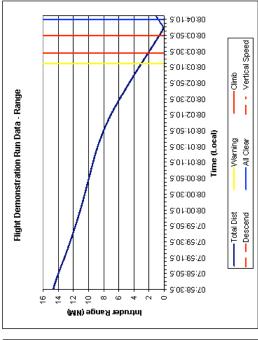
Flight 375 - Run 1 (1.01, Co-Heading, Co-Altitude, TGC, 0/0, 1000 fpm)

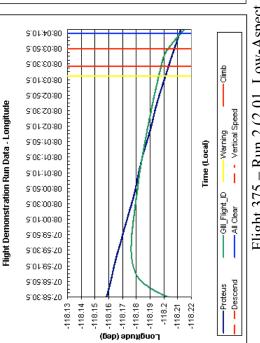
- Warning - Vertical Speed

—GIII_Flight_ID —All Clear

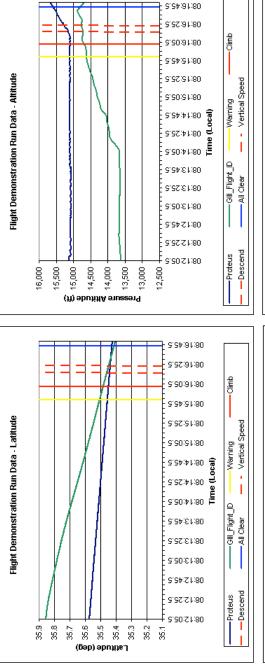
Time (Local)

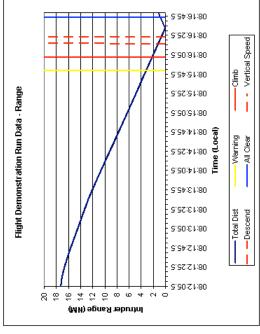


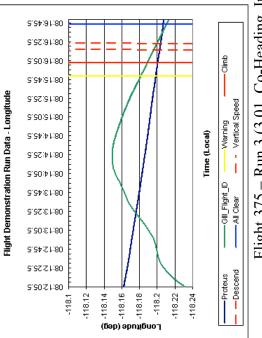




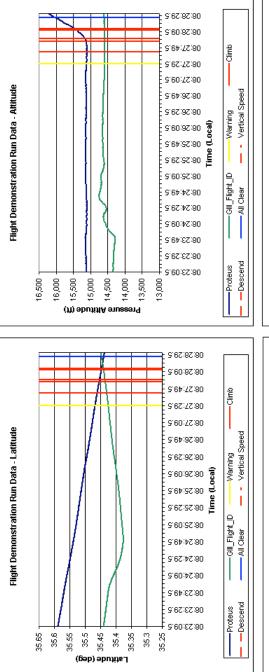
Flight 375 – Run 2 (2.01, Low-Aspect, Co-Altitude, TGC, 0/0, 1000 fpm)

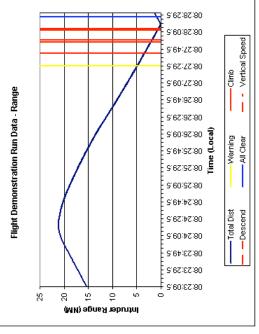






Flight 375 - Run 3 (3.01, Co-Heading, Intruder Climbing, TGC, 0/0, 1000 fpm)





9:62:82:80

9:60:82:80

9164:72:80

8,82;72;80

9160:72:80

9164:92:80

8:82:92:80

9160:97:80

8,95;85;80 8,95;85;80

9160197180

9:64:42:80

08:24:29:5

08:24:09:5

9164:82:80

9:62:82:80

6,80:23:09.5

-117.8 -

-117.7

-117.9

Longitude (deg)

-118.1

-19

-118.3

-117.6

Flight Demonstration Run Data - Longitude

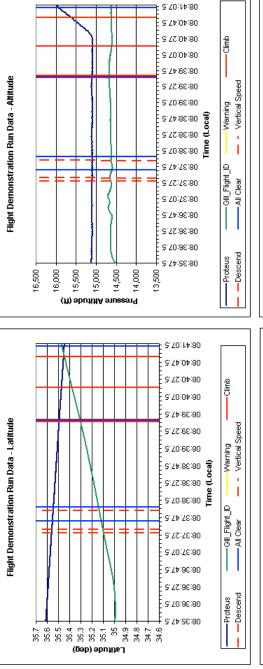
Flight 375 – Run 4 (4.02, Abeam, Co-Altitude, TGC, 4/0, 2500 fpm)

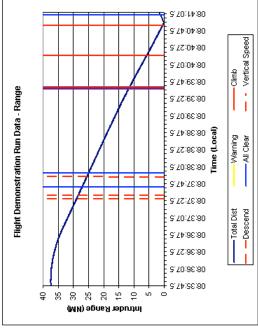
-Climb

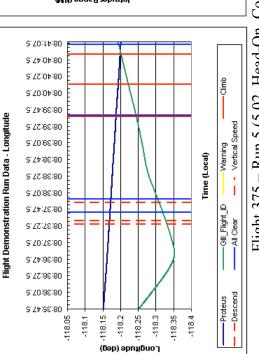
Warning Vertical Speed

— GIII_Flight_ID — All Clear

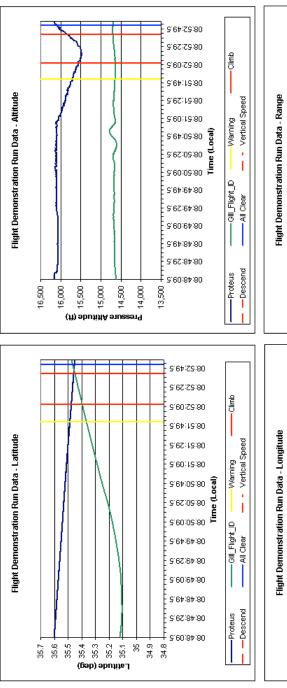
Time (Local)

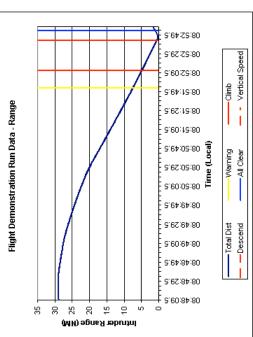


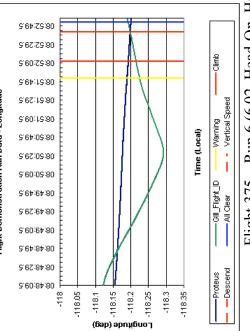




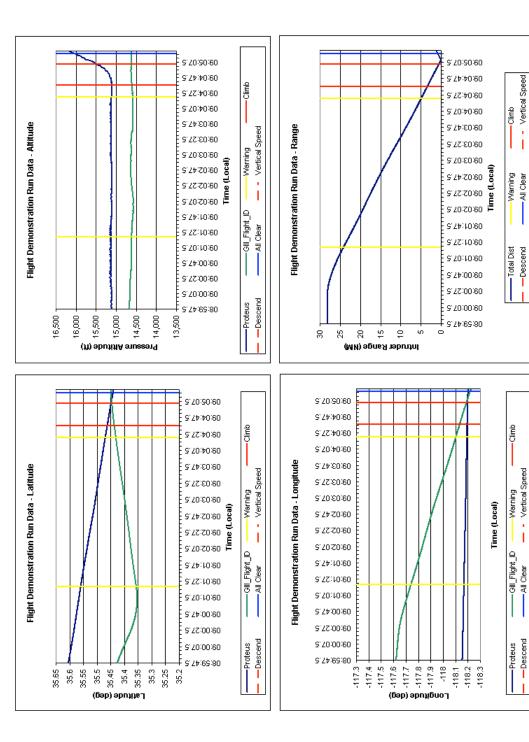
Flight 375 - Run 5 (5.02, Head-On, Co-Altitude, TGC, 4/0, 2500 fpm)



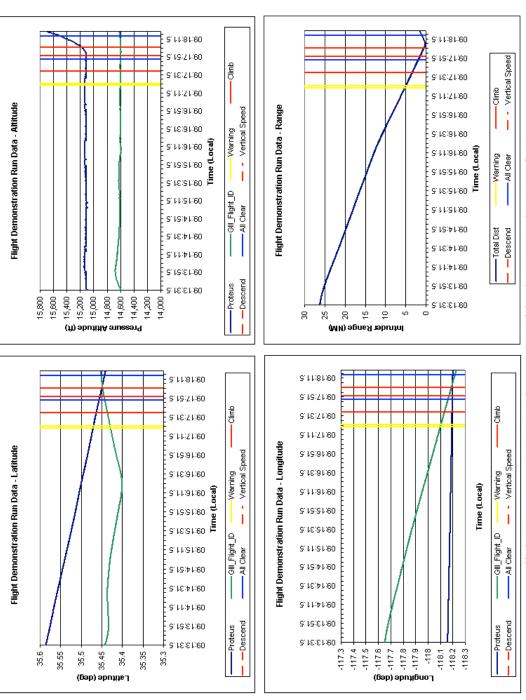




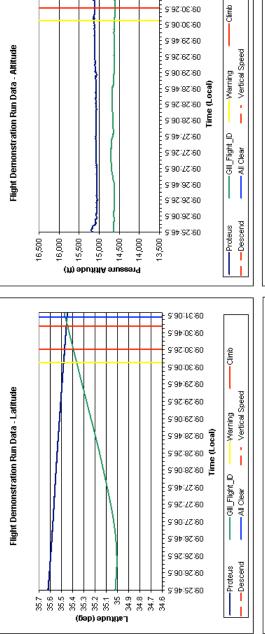
Flight 375 – Run 6 (6.02, Head-On, Host Descending, TGC, 4/0, 2500 fpm)



Flight 375 - Run 7 (4.03, Abeam, Co-Altitude, TGC, 2/0, 2500 fpm)



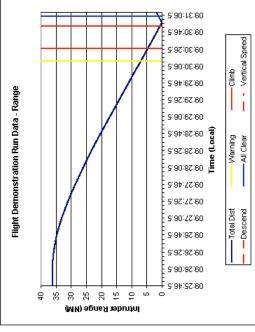
Flight 375 - Run 8 (4.04, Abeam, Co-Altitude, TGC, 0/0, 2500 fpm)

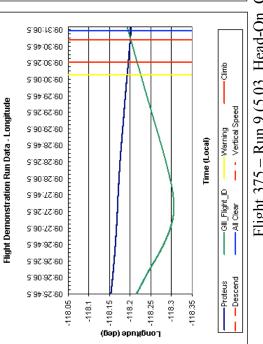


5:30:16:60

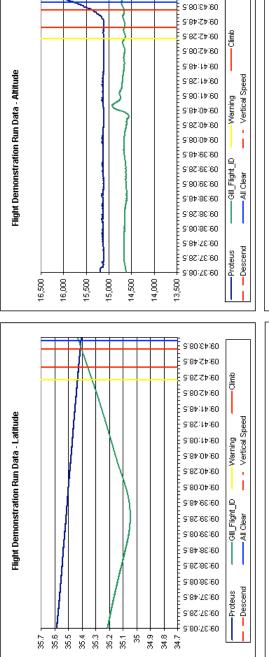
9194108160

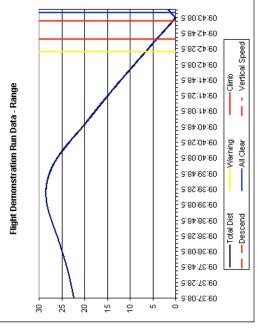
930:30:20





Flight 375 - Run 9 (5.03, Head-On, Co-Altitude, TGC, 2/0, 2500 fpm)





8,89,54,90 8,80,54,90

09:42:28.5

8:84:14:80 8:80:24:90

9187114360

8.80:14:60

9:82:04:60

5:80:04:60

8,84;88;80

9182:66:60

9180168160

8:84:88:60

8.82:88:90

9:80:88:60

9:84:78:60

6,82;78;60

9180128160

-118.05

-118.15

-118.2

-118.25

Flight Demonstration Run Data - Longitude

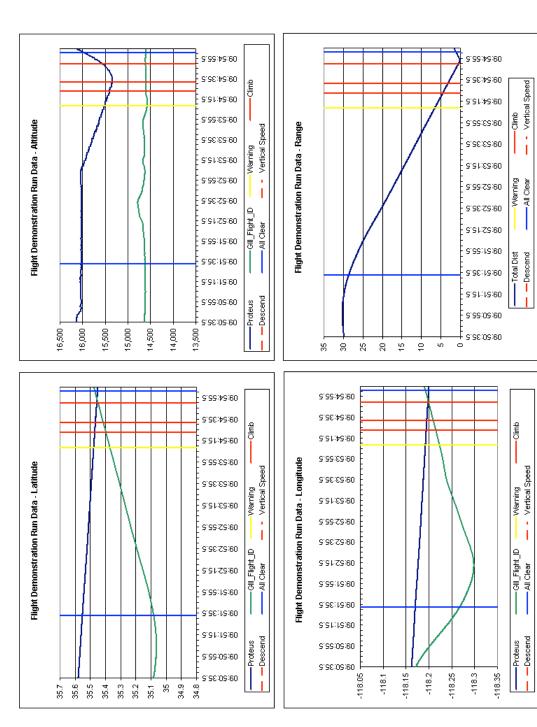
Flight 375 - Run 10 (5.04, Head-On, Co-Altitude, TGC, 0/0, 2500 fpm)

ë E

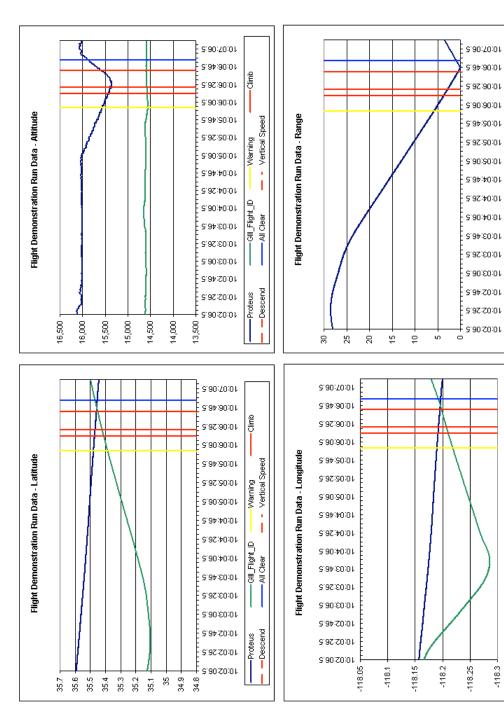
Warning — Vertical Speed

—GIII_Flight_ID —All Clear

-118.35



Flight 375 - Run 11 (6.03, Head-On, Host Descending, TGC, 2/0, 2500 fpm)



Flight 375 - Run 12 (6.04, Head-On, Host Descending, TGC, 0/0, 2500 fpm)

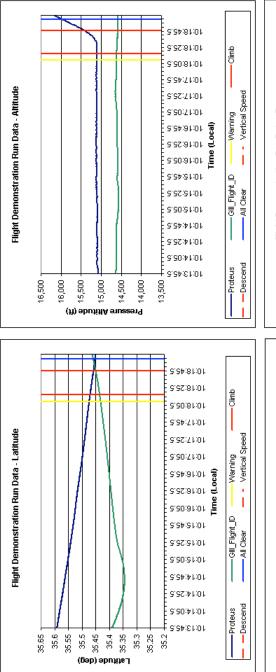
Total Dist -Descend

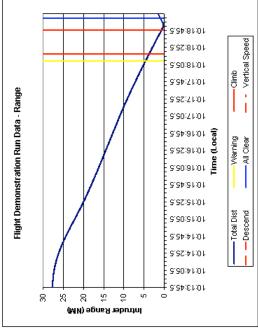
-Climb

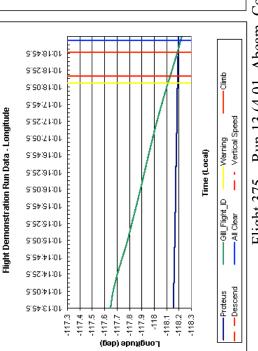
— GIII_Flight_ID — All Clear

-Descend -Proteus

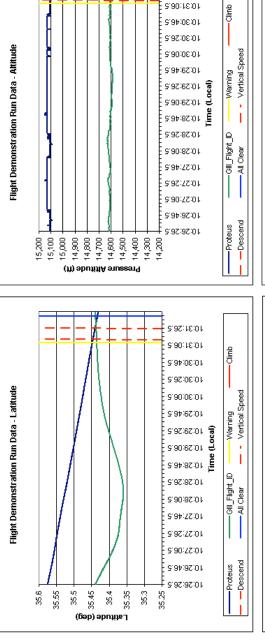
-118.3



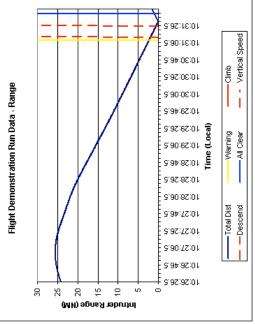


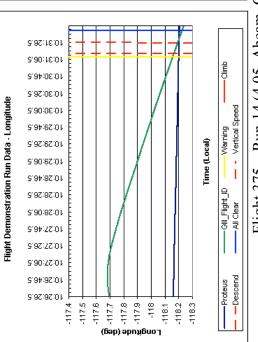


Flight 375 – Run 13 (4.01, Abeam, Co-Altitude, TGC, 6/0, 2500 fpm)

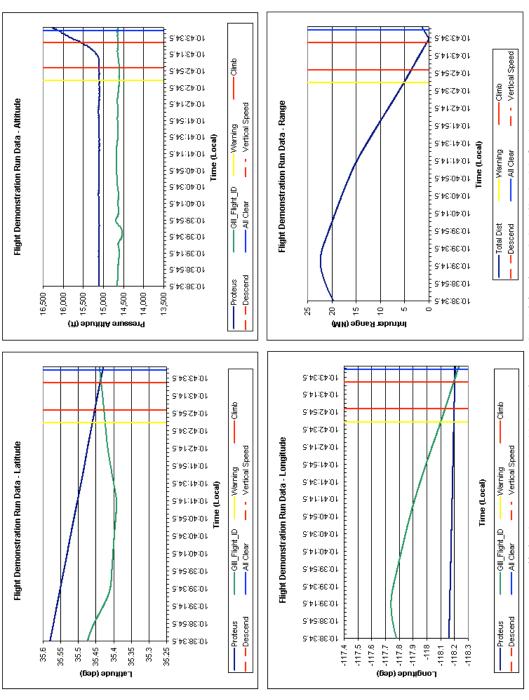


3.92:16:01

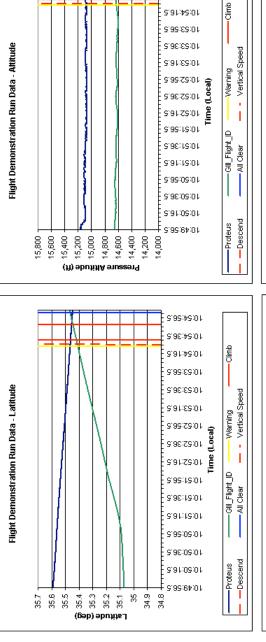




Flight 375 - Run 14 (4.05, Abeam, Co-Altitude, TGC, 0/0, 2500 fpm)

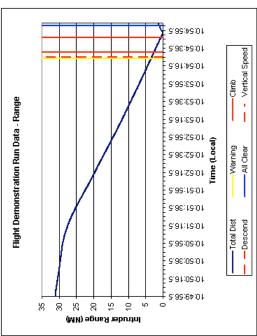


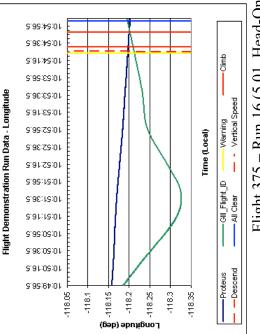
Flight 375 - Run 15 (4.06, Abeam, Co-Altitude, TGC, 4/2, 2500 fpm)



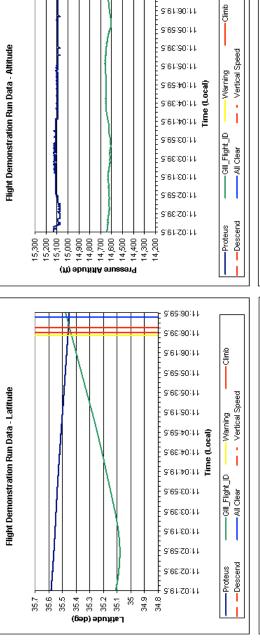
3.88:48:01

3,36,36,01

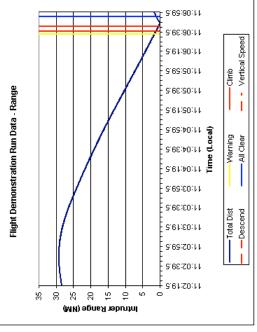




Flight 375 - Run 16 (5.01, Head-On, Co-Altitude, TGC, 6/0, 2500 fpm)



8,88:80:11 8,88:80:11



8,88:80:11 8,88:80:11

9161/90/11

9169390311

9168390111

9161/30/11

9189:40:11

9168340111

9181/40/11

9169180111

9168:80:11

9161/200/11

11:05:59:5

11:02:39:5

11:02:19:5

-118.1

-118.05

-118.15

Longitude (deg)

Flight Demonstration Run Data - Longitude

Flight 375 - Run 17 (5.05, Head-On, Co-Altitude, TGC, 0/0, 2500 fpm)

-Climb

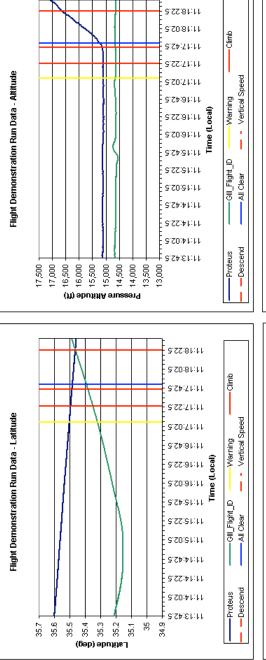
—GIII_Flight_ID —All Clear

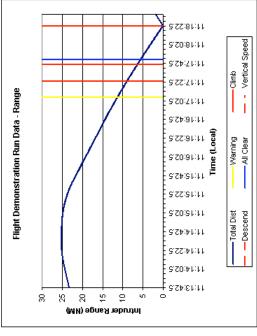
-Descend

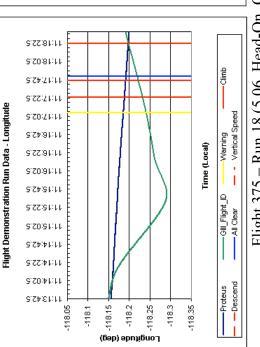
-Proteus

-118.35

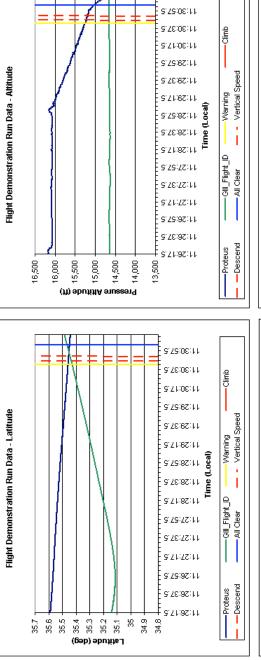
Time (Local)

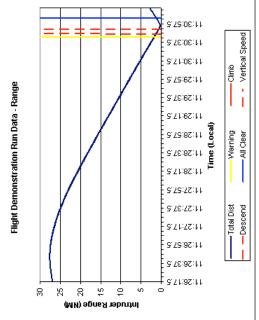


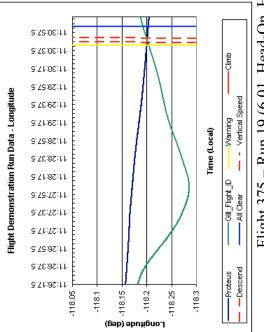




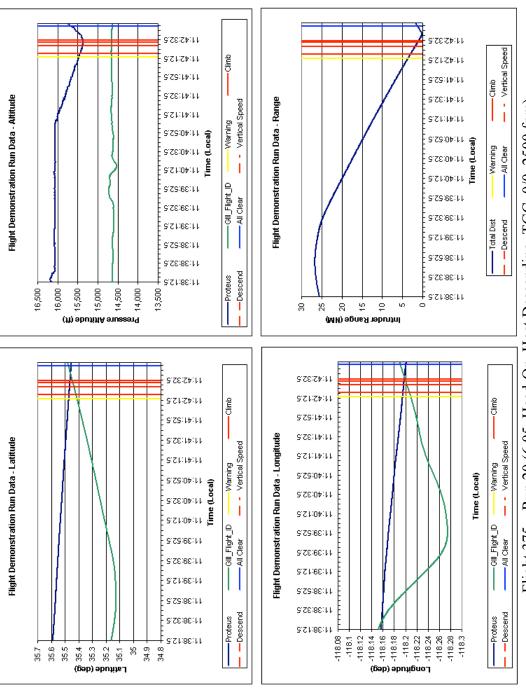
Flight 375 - Run 18 (5.06, Head-On, Co-Altitude, TGC, 4/2, 2500 fpm)



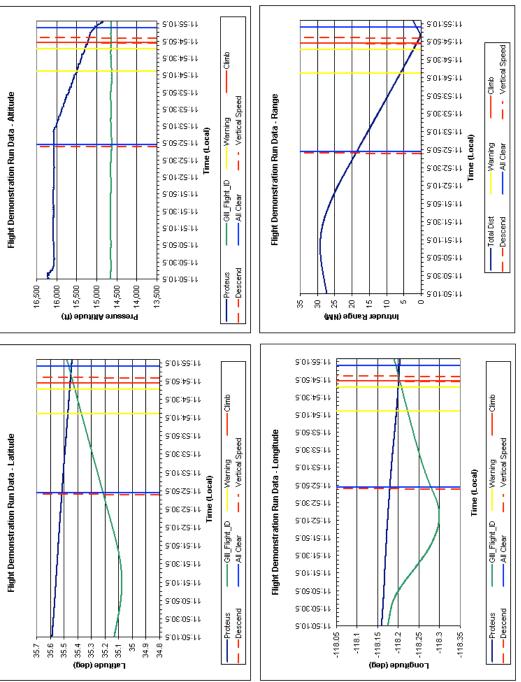




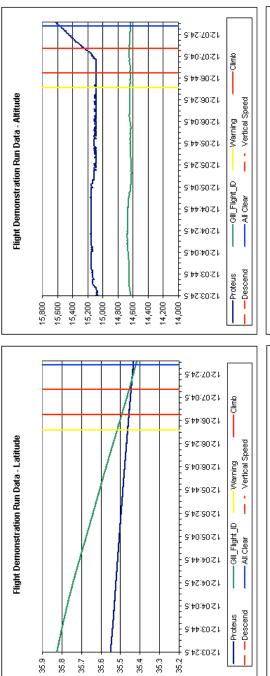
Flight 375 – Run 19 (6.01, Head-On, Host Descending, TGC, 6/0, 2500 fpm)

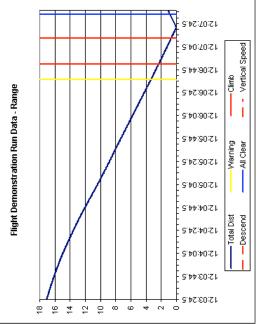


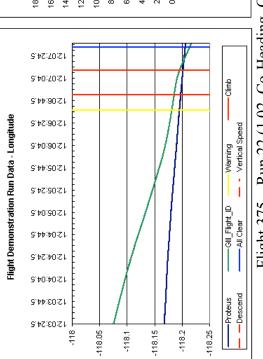
Flight 375 - Run 20 (6.05, Head-On, Host Descending, TGC, 0/0, 2500 fpm)



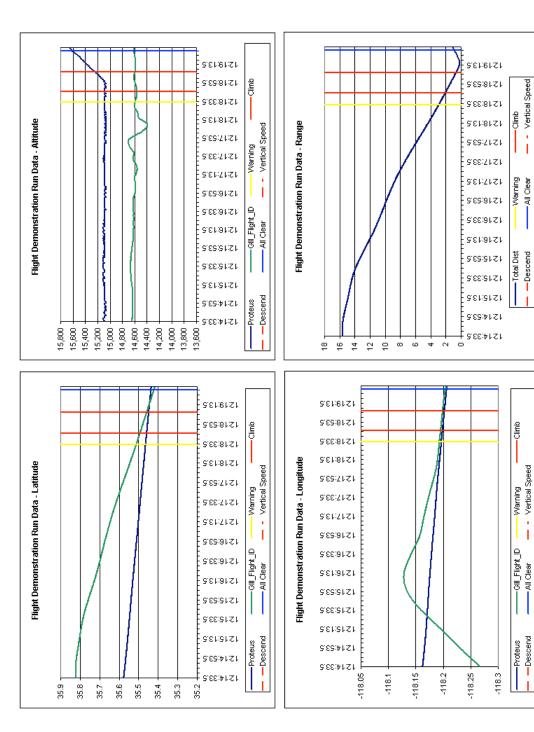
Flight 375 - Run 21 (6.06, Head-On, Host Descending, TGC, 4/2, 2500 fpm)







Flight 375 – Run 22 (1.02, Co-Heading, Co-Altitude, AGA, 0/0, 1000 fpm)

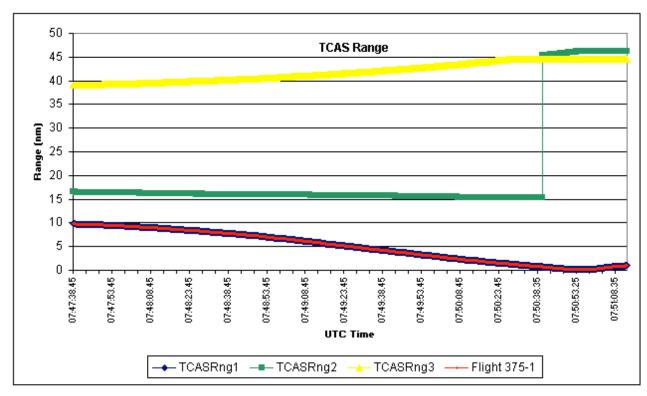


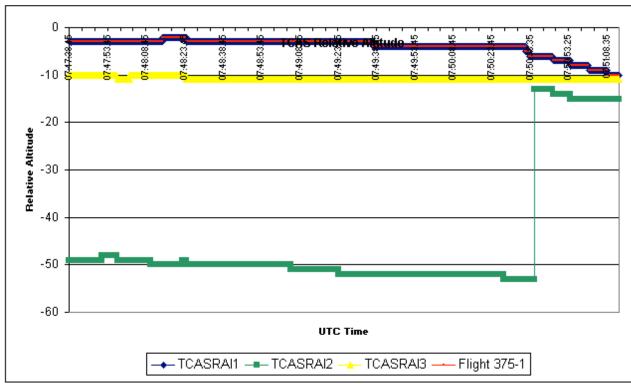
Flight 375 – Run 23 (2.02, Low-Aspect, Co-Altitude, AGA, 0/0, 1000 fpm)

-All Clear

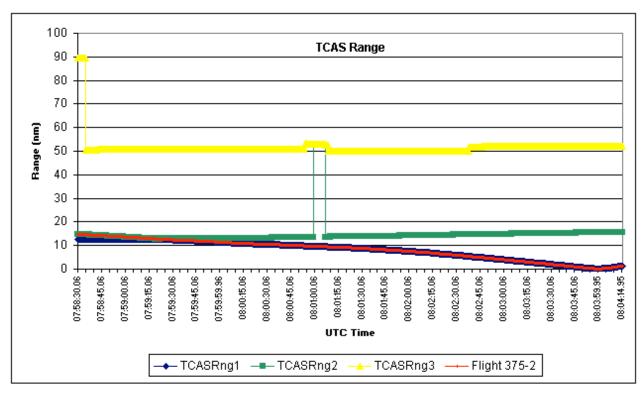
-- Descend

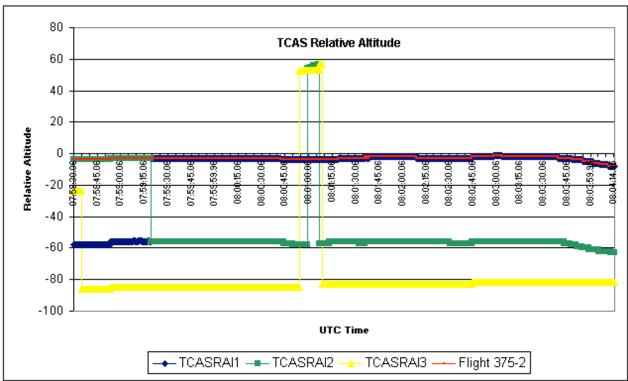
Cimb



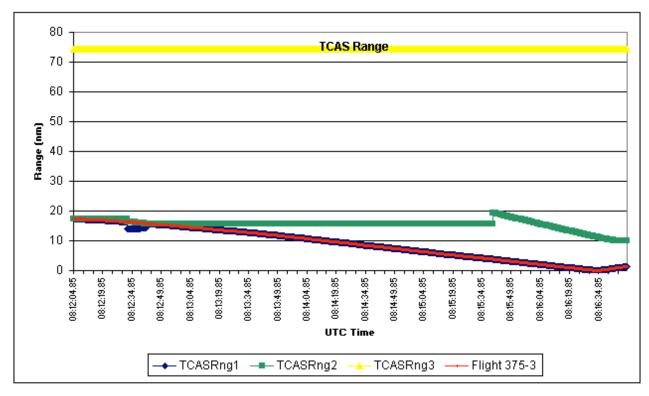


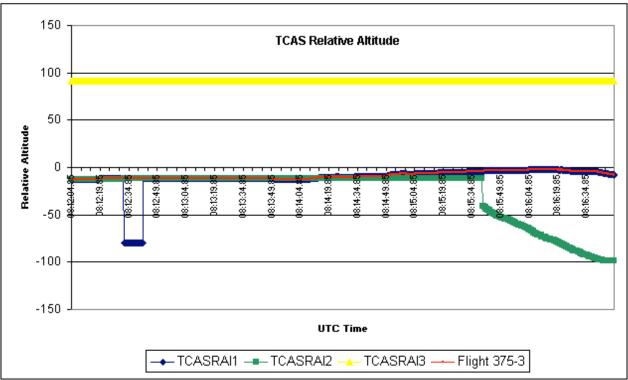
TCAS Track Data Flight 375, Run 1



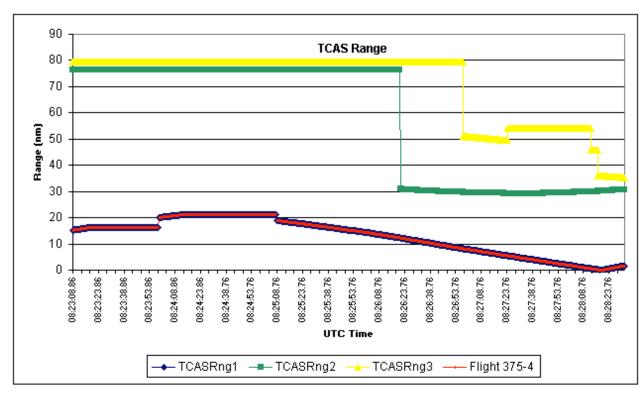


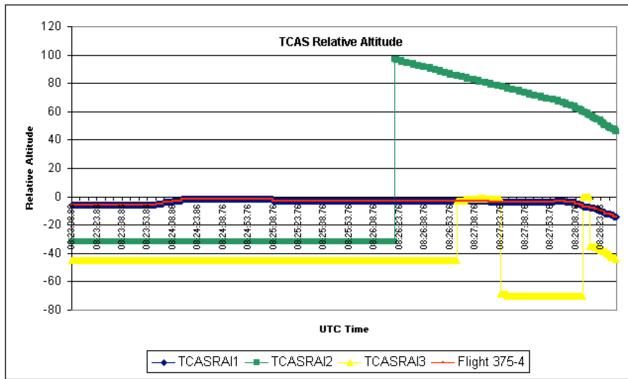
TCAS Track Data Flight 375, Run 2



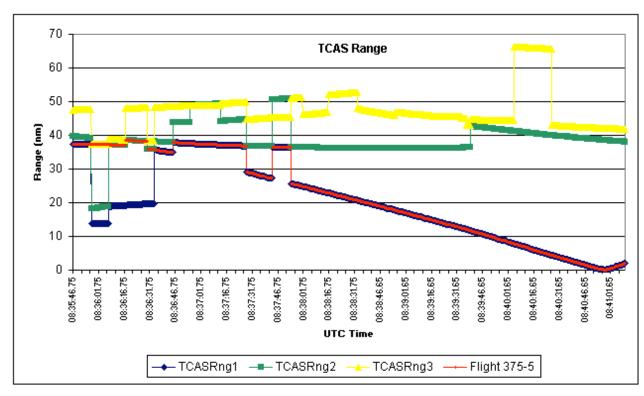


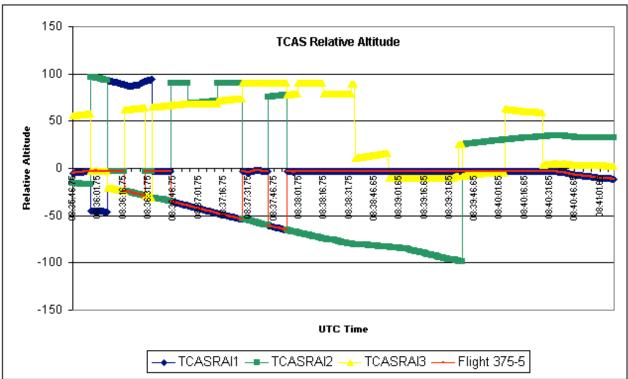
TCAS Track Data Flight 375, Run 3



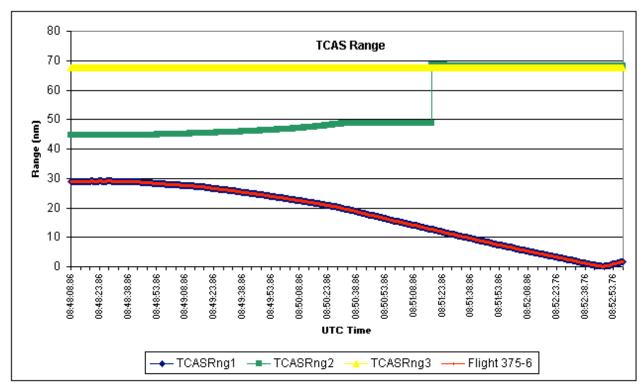


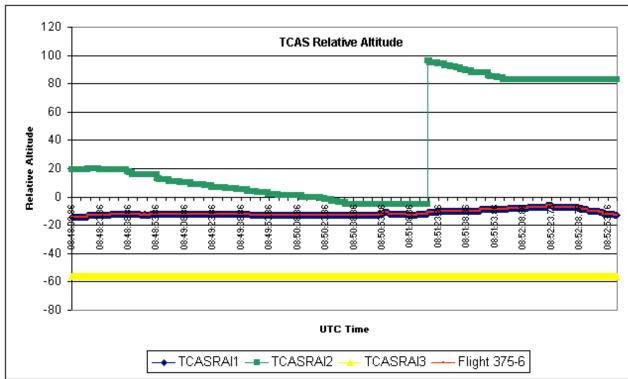
TCAS Track Data Flight 375, Run 4



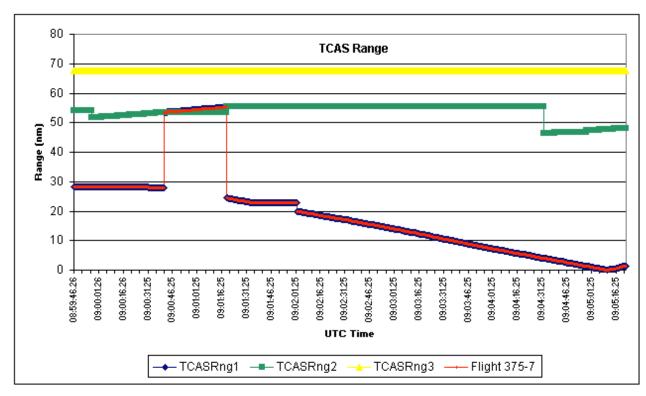


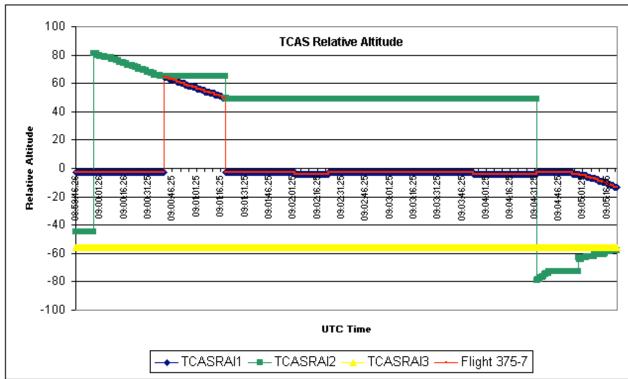
TCAS Track Data Flight 375, Run 5



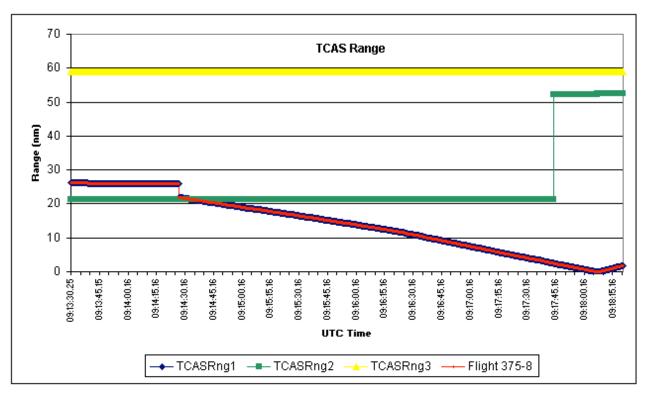


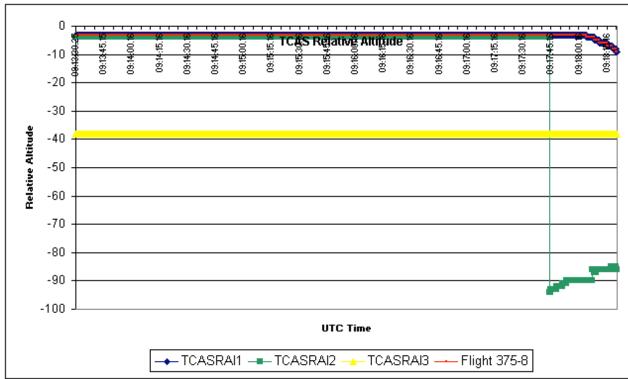
TCAS Track Data Flight 375, Run 6



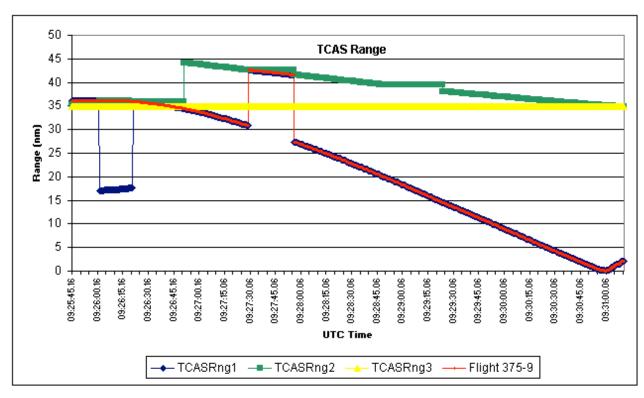


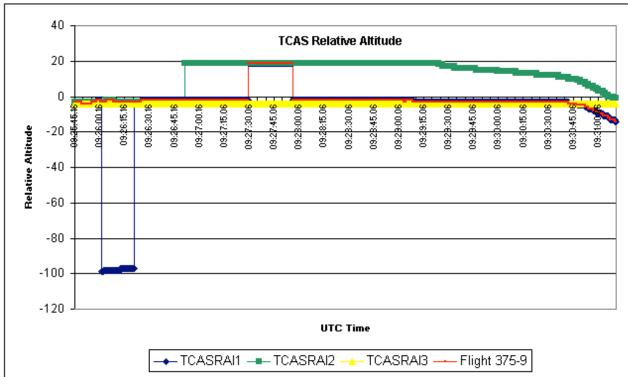
TCAS Track Data Flight 375, Run 7



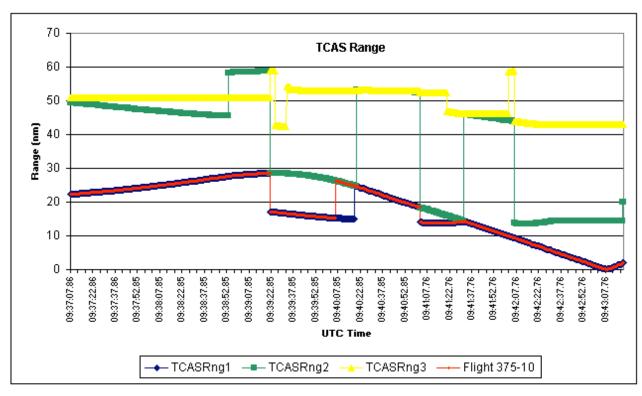


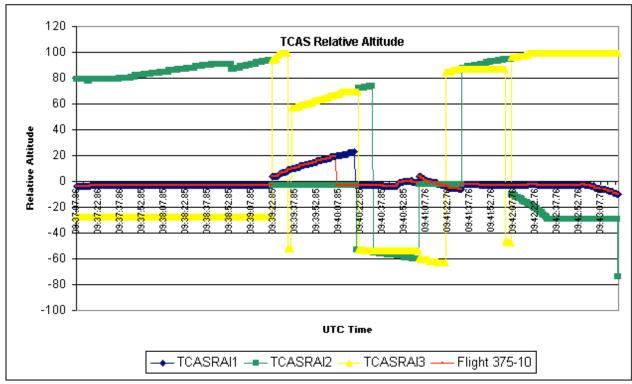
TCAS Track Data Flight 375, Run 8



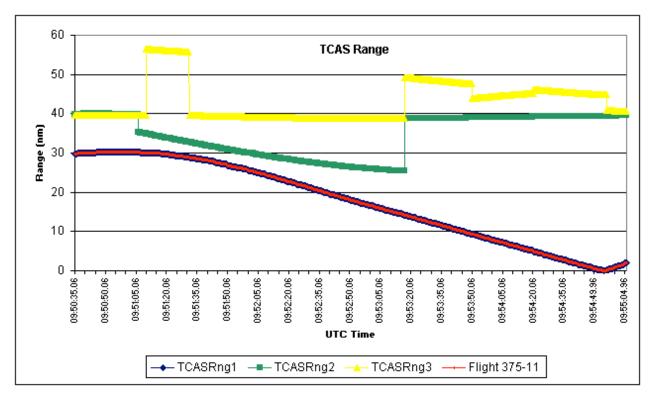


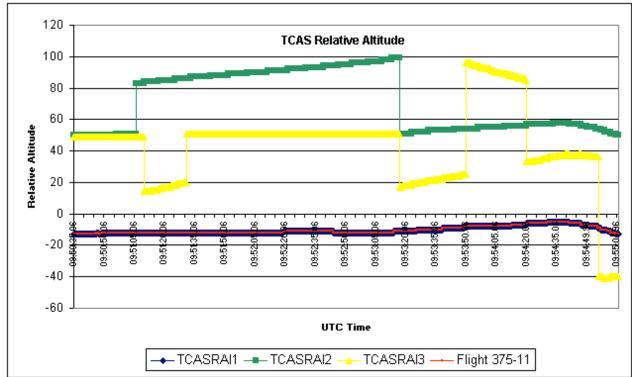
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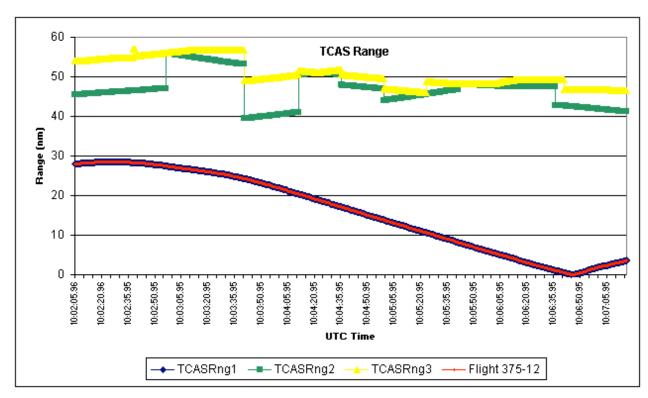


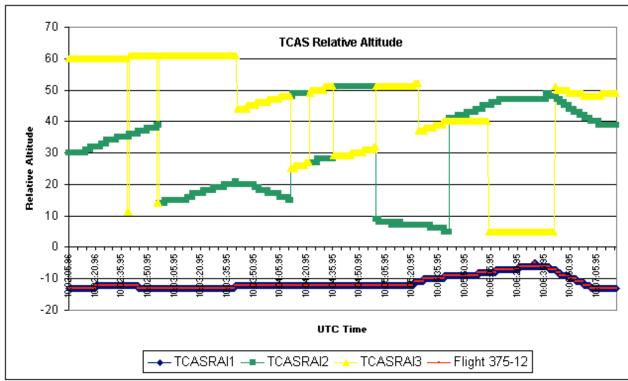
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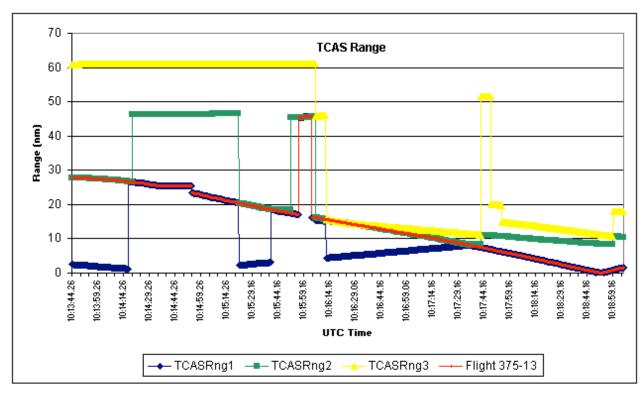


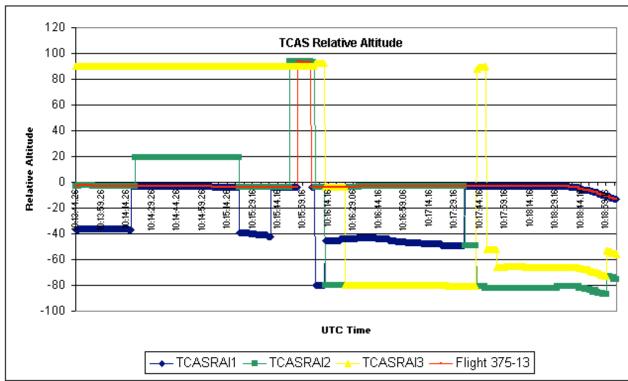
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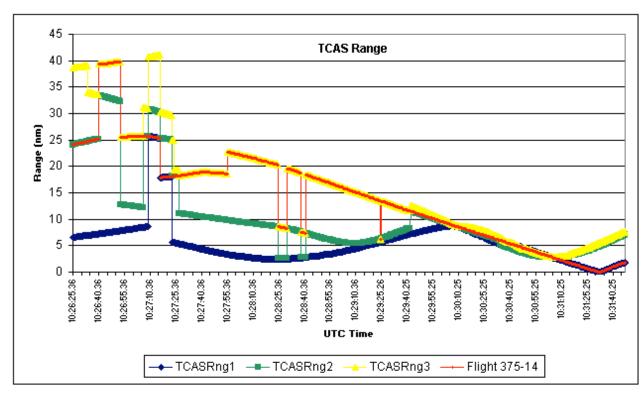


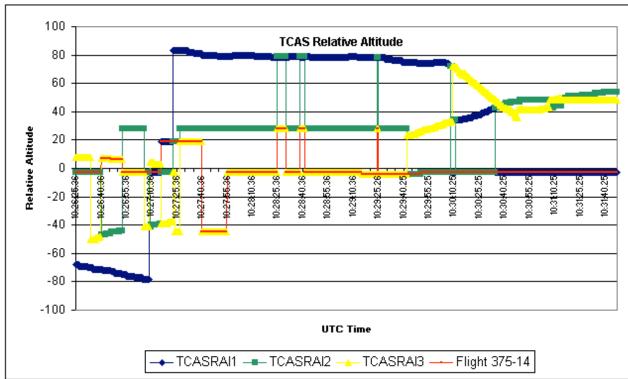
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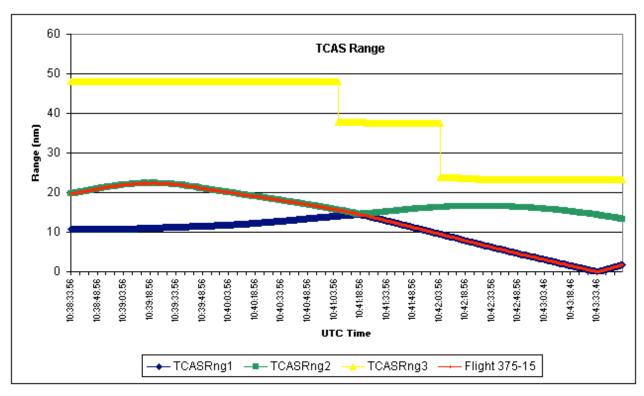


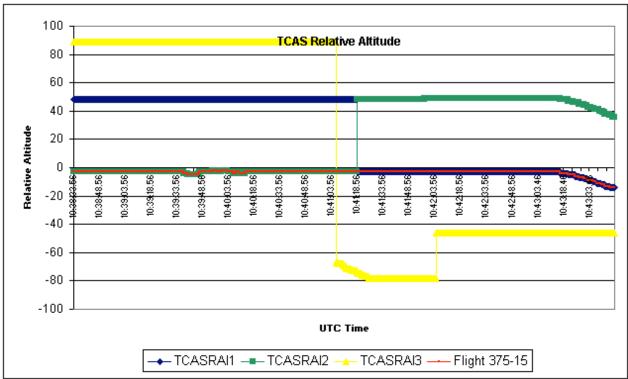
TCAS Track Data Flight 375, Run 13



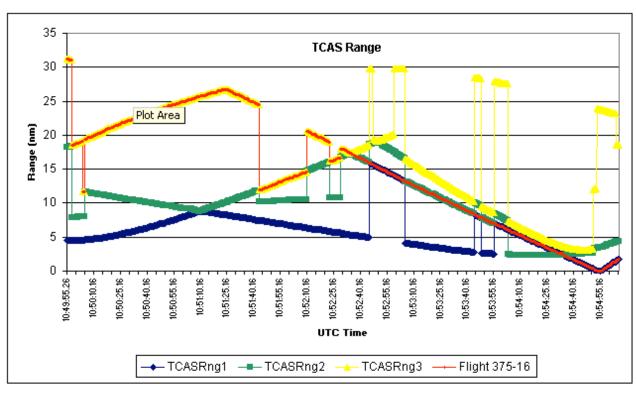


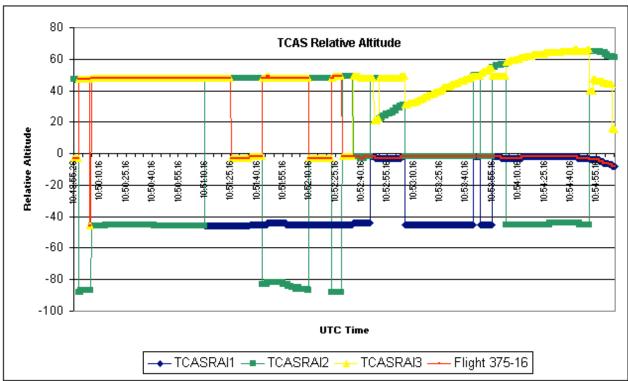
TCAS Track Data Flight 375, Run 14



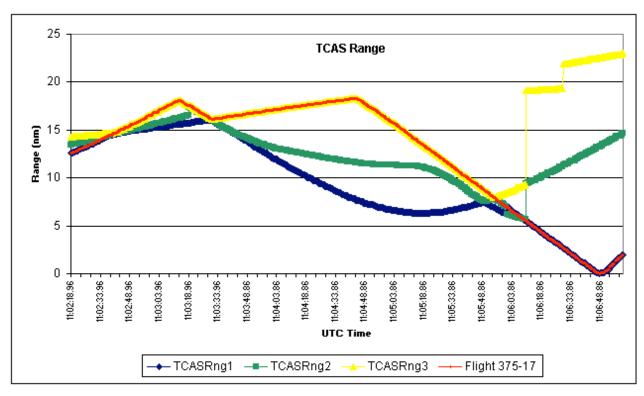


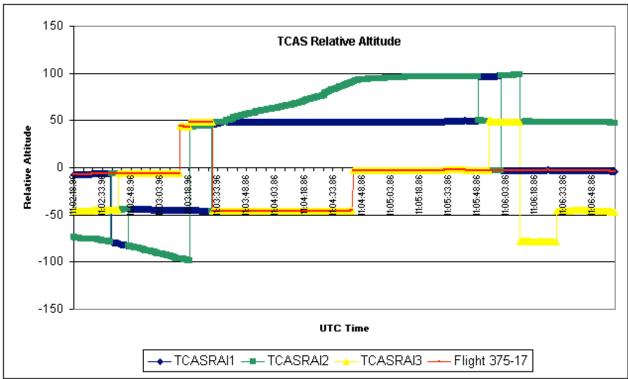
TCAS Track Data Flight 375, Run 15



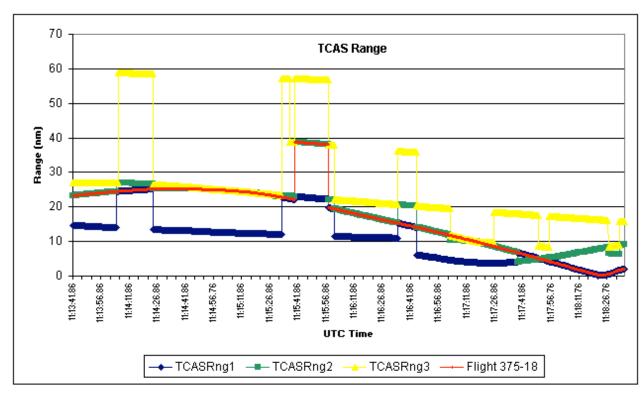


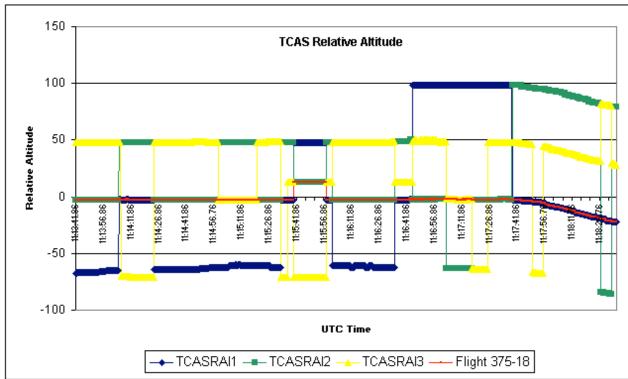
TCAS Track Data Flight 375, Run 16



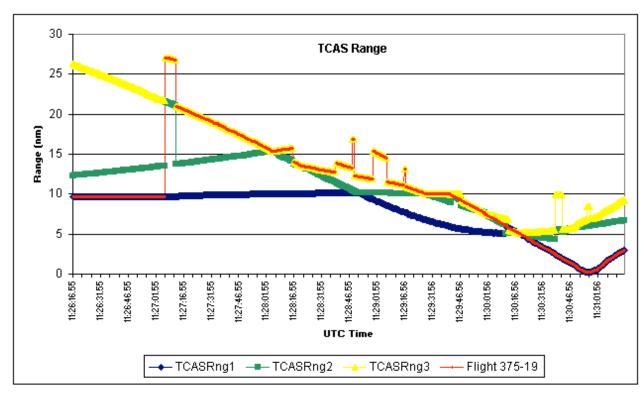


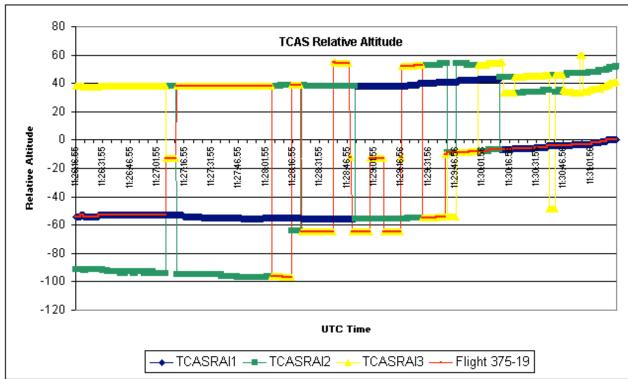
TCAS Track Data Flight 375, Run 17



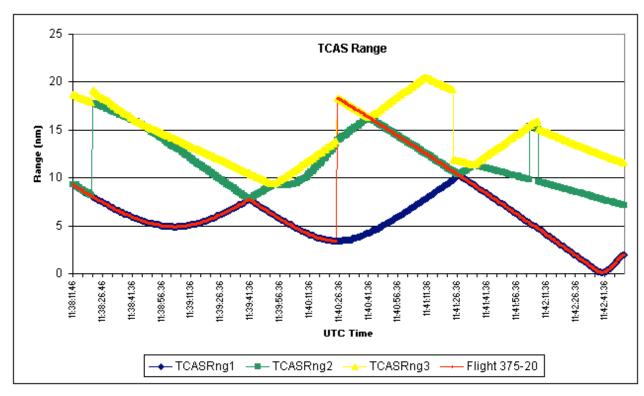


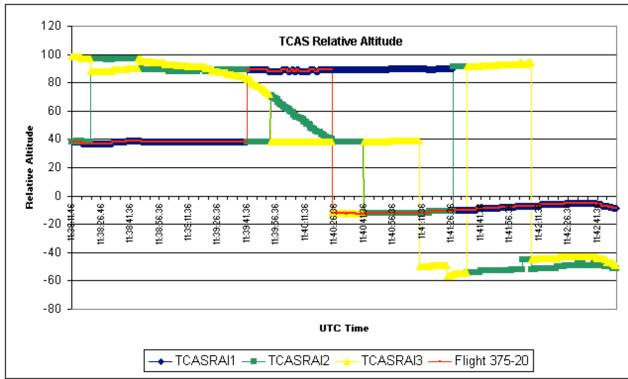
TCAS Track Data Flight 375, Run 18



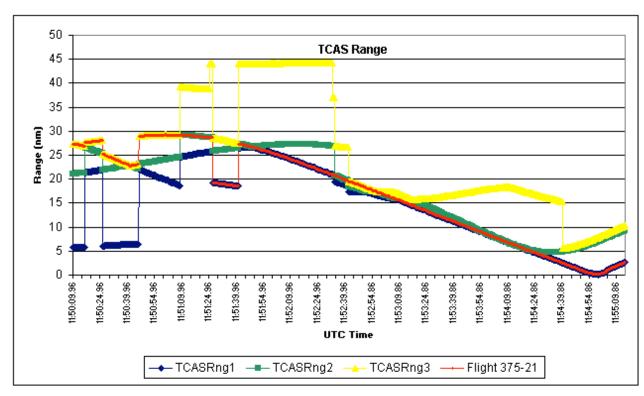


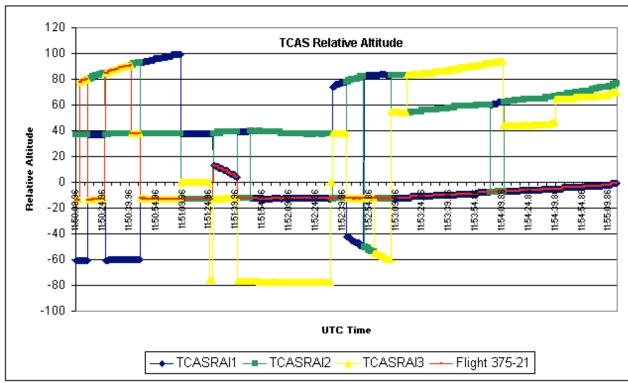
TCAS Track Data Flight 375, Run 19



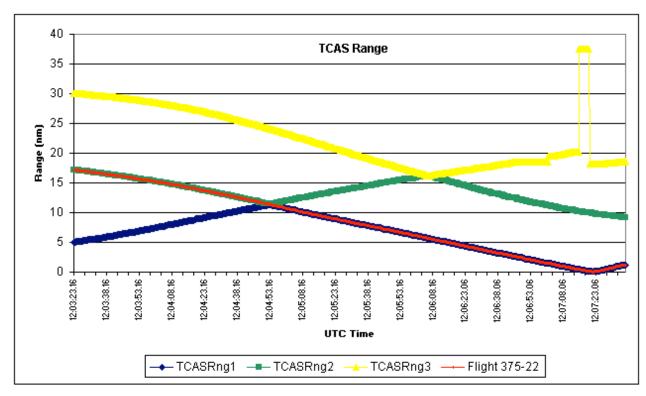


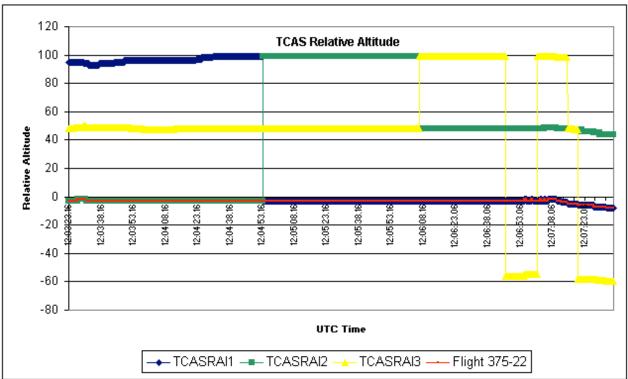
TCAS Track Data Flight 375, Run 20



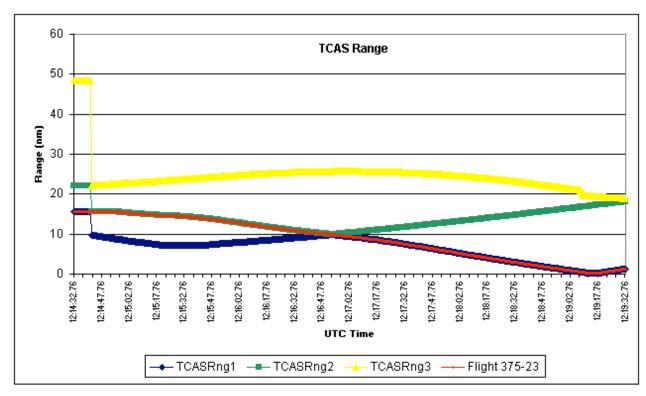


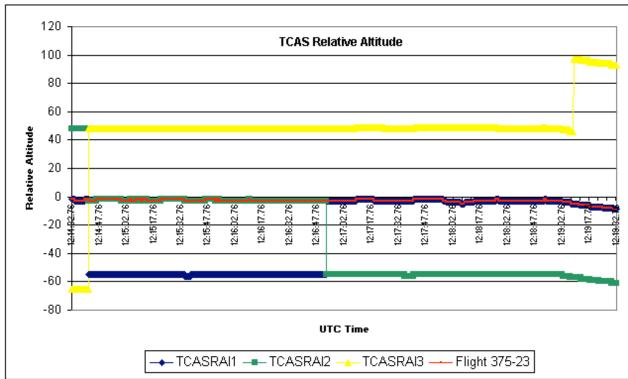
TCAS Track Data Flight 375, Run 21





TCAS Track Data Flight 375, Run 22

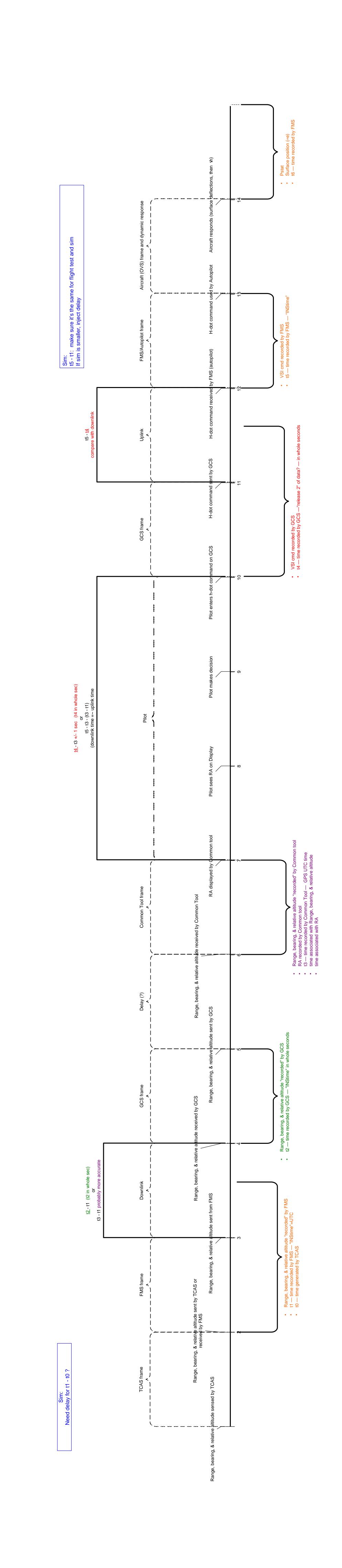




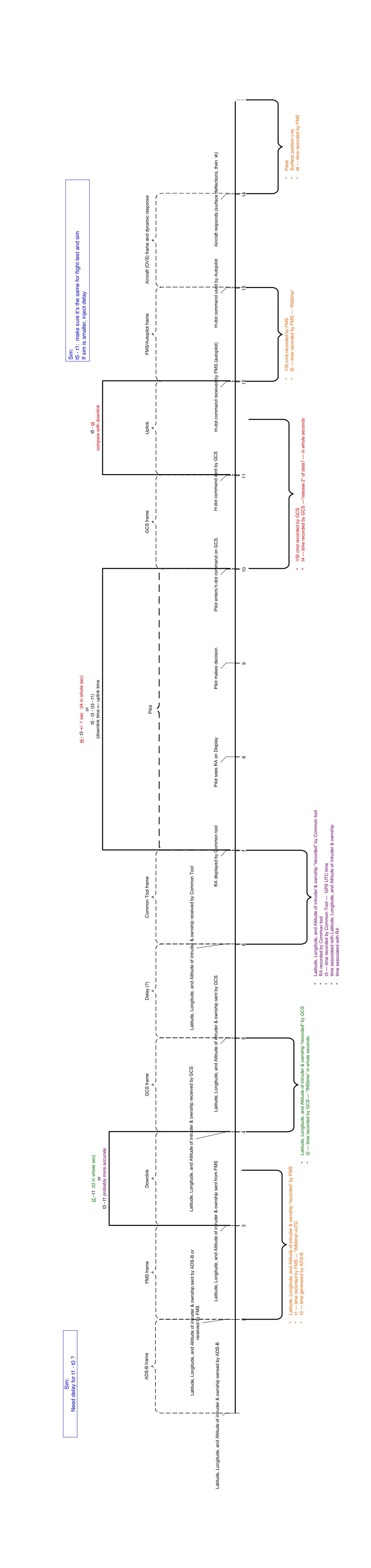
TCAS Track Data Flight 375, Run 23

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Timeline for RA Generated by Onboard TCAS



imeline for RA Generated by GCAS Using TCAS as Sensor

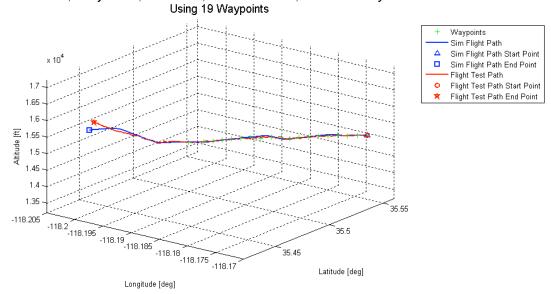


Timeline for RA Generated by GCAS Using ADS-B as Sensor

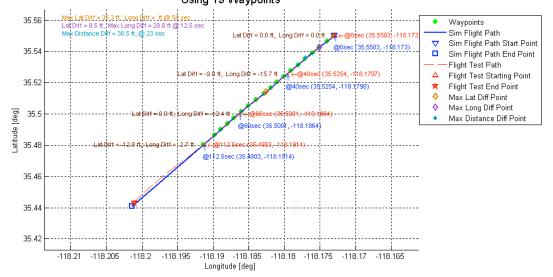
Flight 375 Run 1

Proteus 3-D Plot
Flight No. 375 Run No. 1
Scenario 1.01 Co-Heading, Co-Altitude

Scenario 1.01 Co-Heading, Co-Altitude Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC

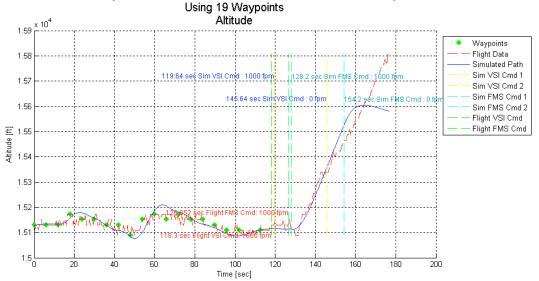


Proteus Flight Path Position Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

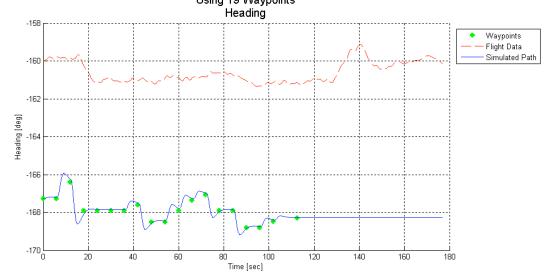


Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC

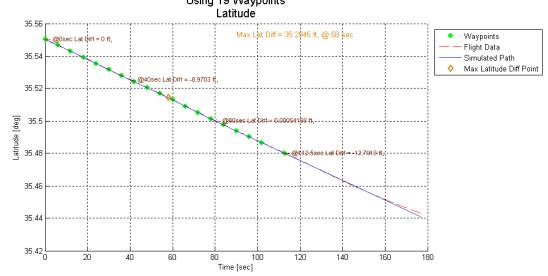


Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

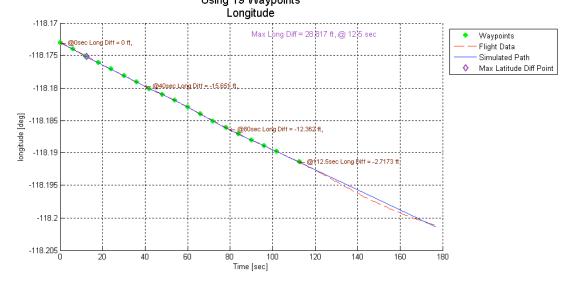


Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC Using 19 Waypoints



Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude



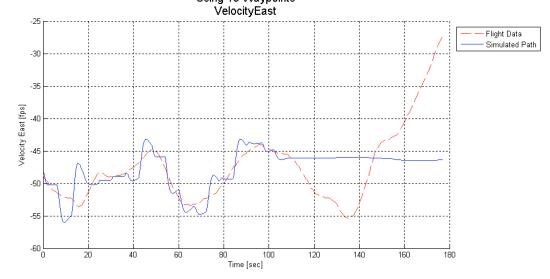
Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC

Using 19 Waypoints
VelocityDown

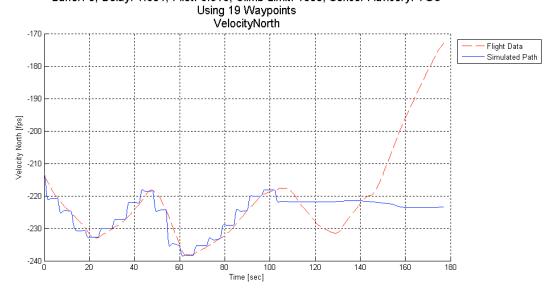
Flight Data
Simulated Path

Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

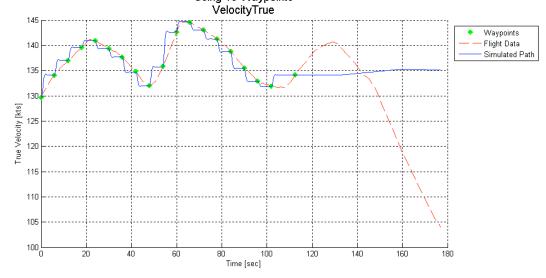


Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC

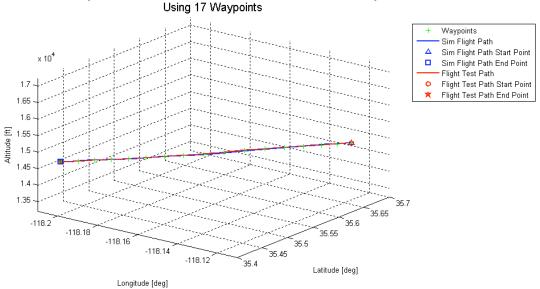


Proteus Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

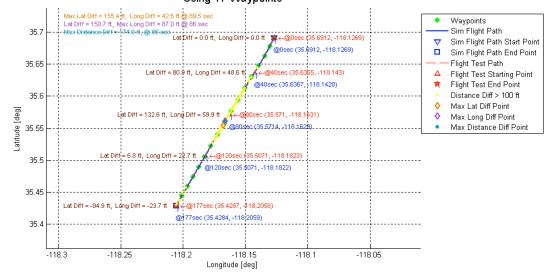


Generic G-III 3-D Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Inhibit: 1000; Sensor Advisory: TGC

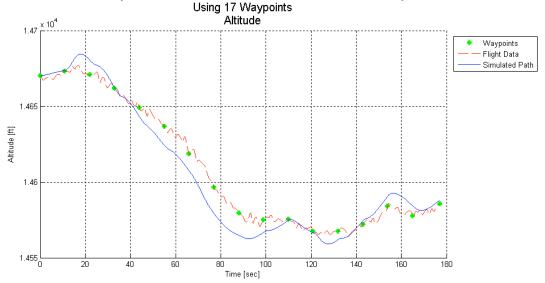


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

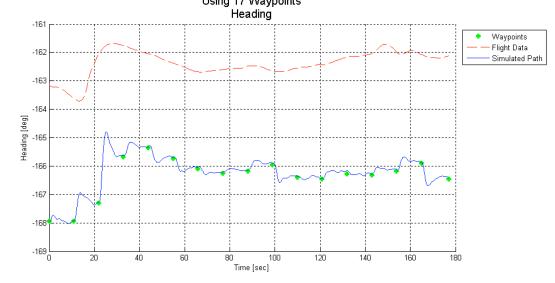


Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC



Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude



Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC Using 17 Waypoints

> Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC Using 17 Waypoints

Longitude -118.11 Waypoints Flight Data Simulated Path Max Latitude Diff Point -118.13 -118.14 longitude [deg] -118.16 -118.18 -118.19 -118.21 L 80 Time [sec] 120 140 160 180

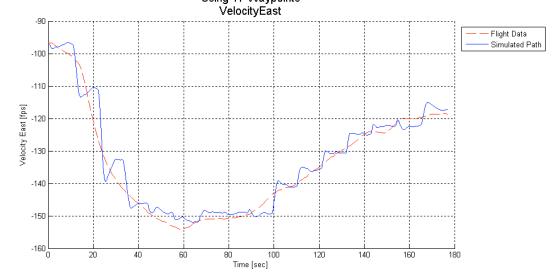
Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC

Using 17 Waypoints
VelocityDown

Flight Data
Simulated Path

Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude



Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC Using 17 Waypoints

VelocityNorth

-420

-440

-460

-480

-520

-540

-600

-600

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-600

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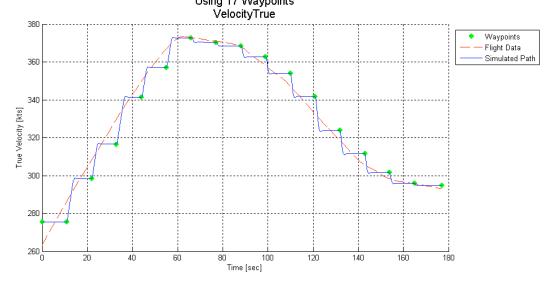
-600

-600

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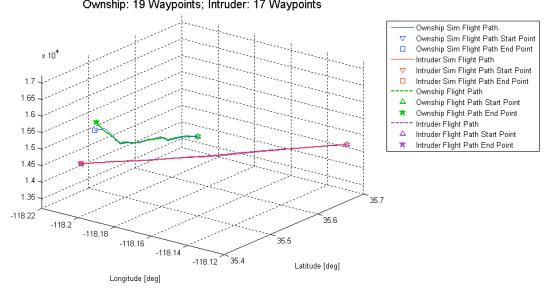
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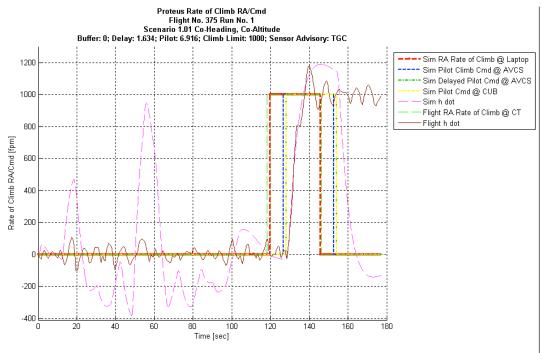
Generic G-III Time History Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

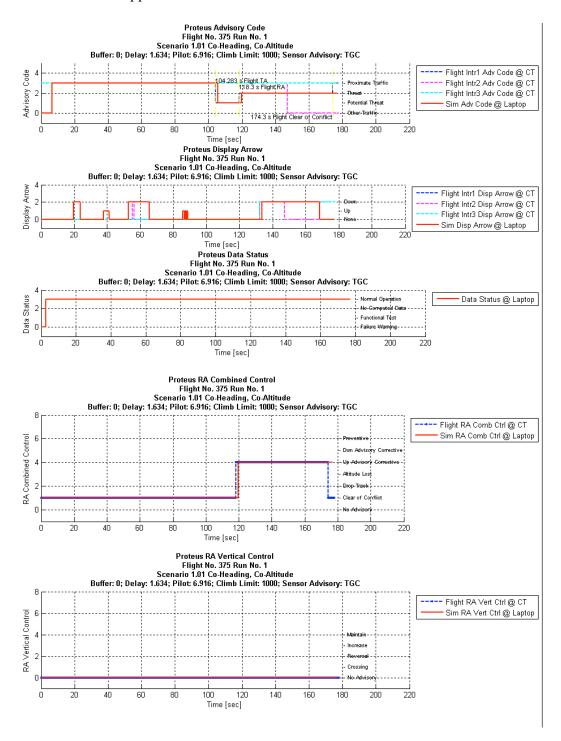


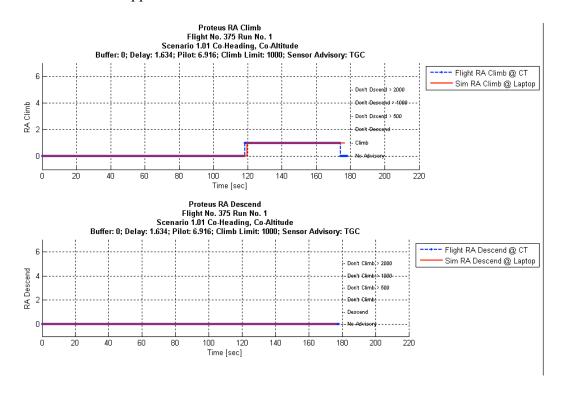
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 1 Scenario 1.01 Co-Heading, Co-Altitude

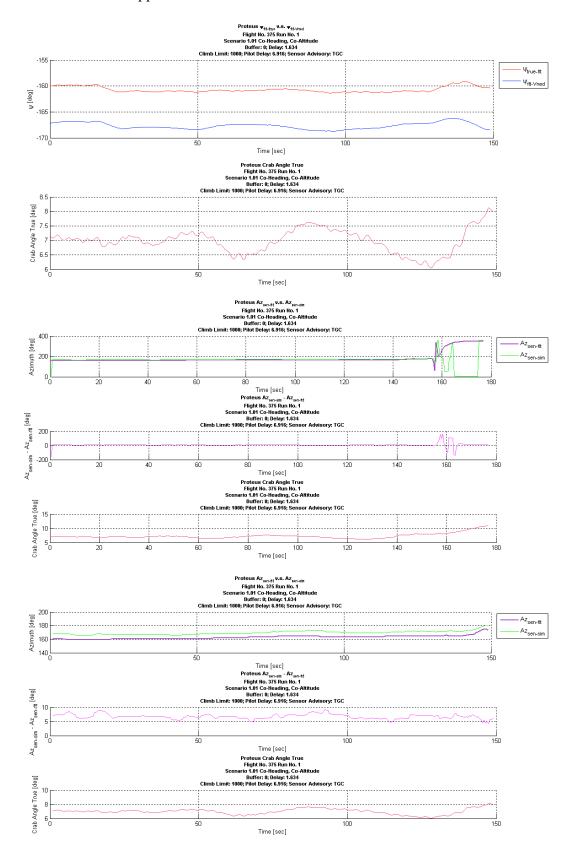
Buffer: 0; Delay: 1.634; Pilot: 6.916; Climb Limit: 1000; Sensor Advisory: TGC Ownship: 19 Waypoints; Intruder: 17 Waypoints

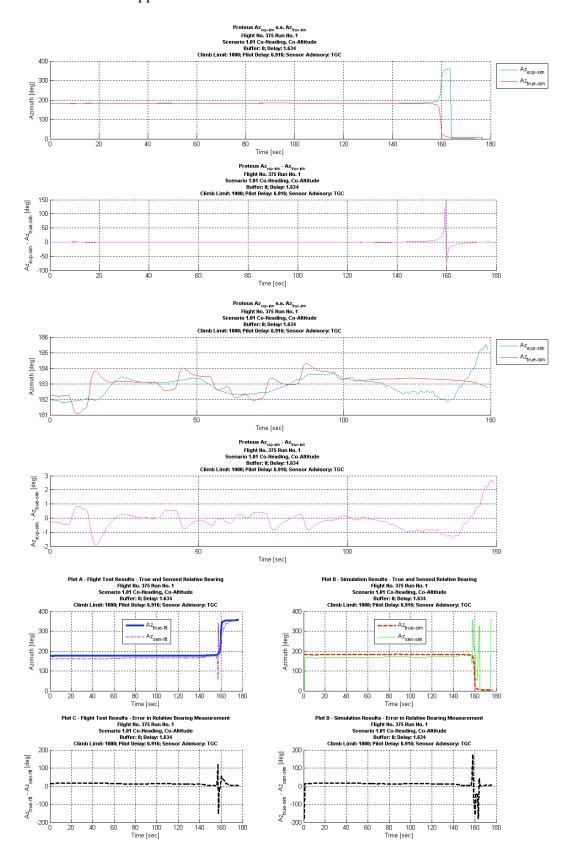


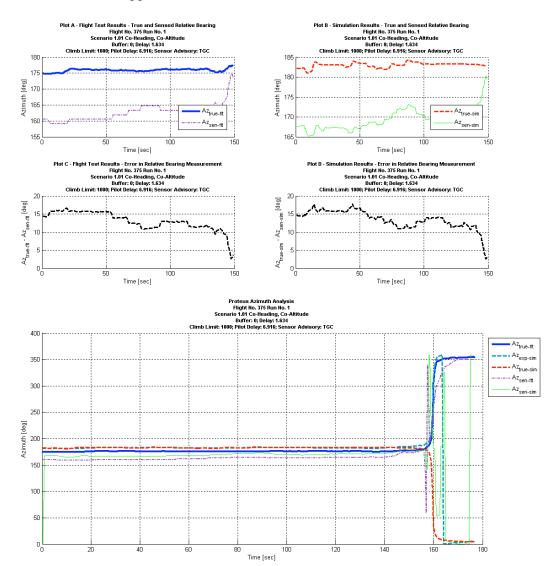


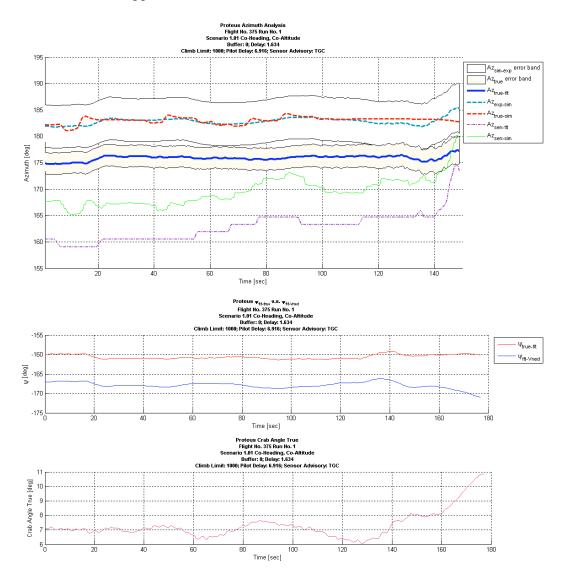


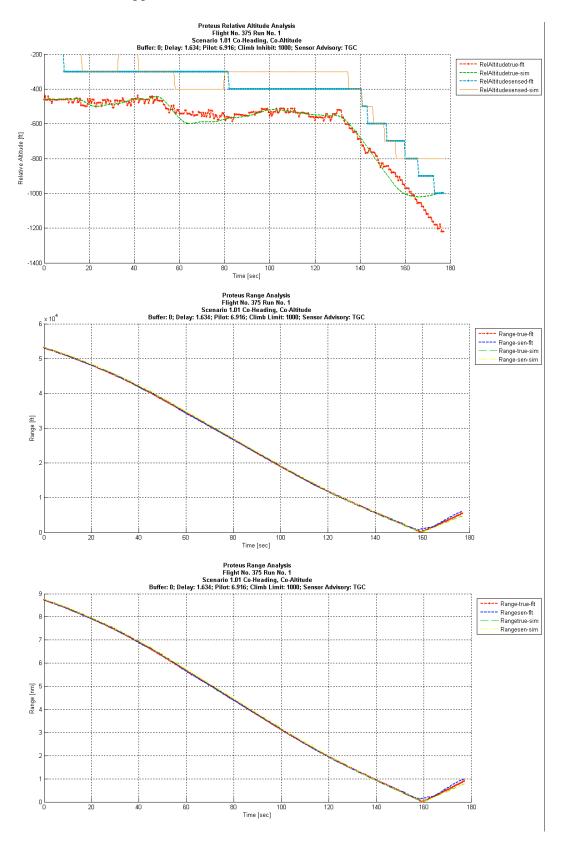






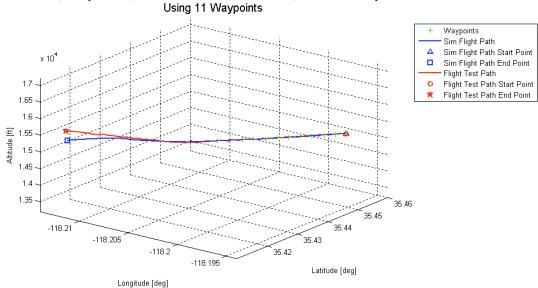




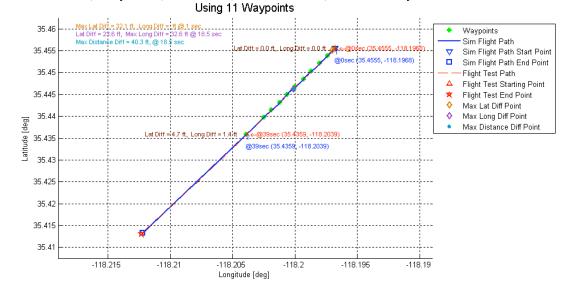


Flight 375 Run 2

Proteus 3-D Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude Buffer: 0; Delay: 1.634; Pilot: 3.4053; Climb Limit: 1000; Sensor Advisory: TGC

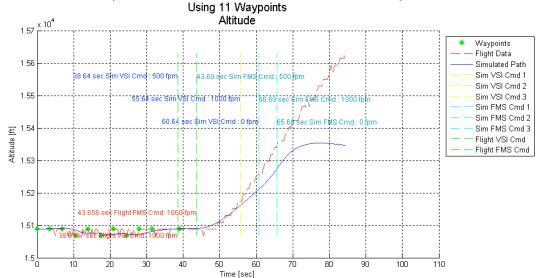


Proteus Flight Path Position Plot
Flight No. 375 Run No. 2
Scenario 2.01 Low-Aspect, Co-Altitude
Buffer: 0; Delay: 1.634; Pilot: 3.4053; Climb Limit: 1000; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.4053; Climb Limit: 1000; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.4053; Climb Limit: 1000; Sensor Advisory: TGC Using 11 Waypoints

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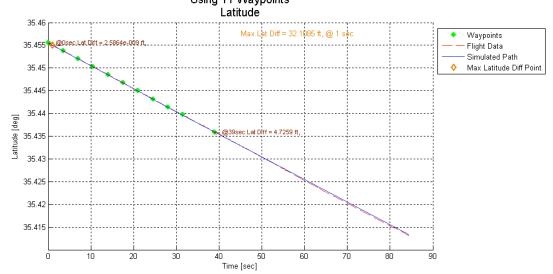
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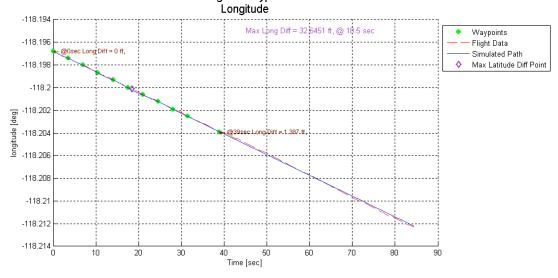
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Proteus Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

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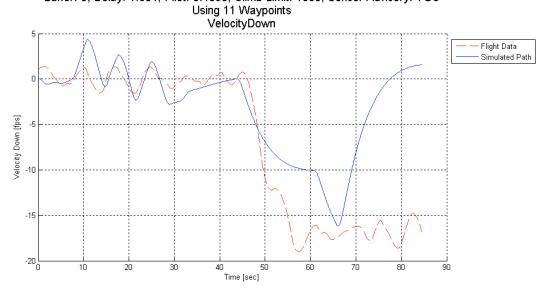


Proteus Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude



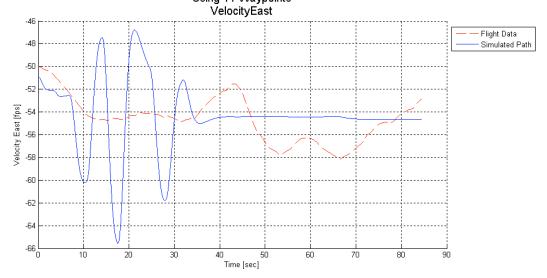
Proteus Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

Scenario 2.01 Low-Aspect, Co-Altitude
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Proteus Time History Plot Flight No. 375 Run No. 2 rio 2.01 Low-Aspect. Co-Altitud

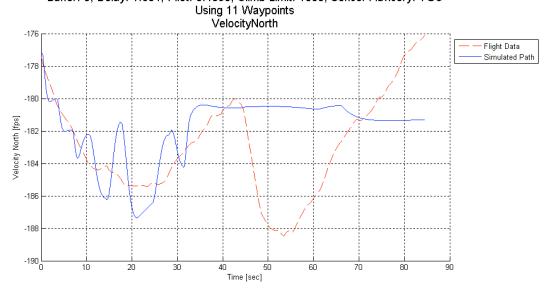
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Using 11 Waypoints



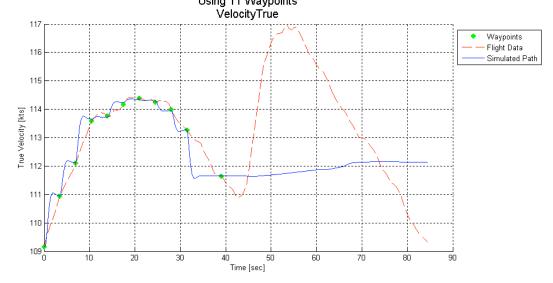
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Scenario 2.01 Low-Aspect, Co-Altitude

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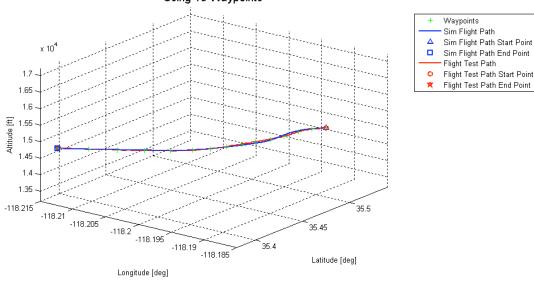


Proteus Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

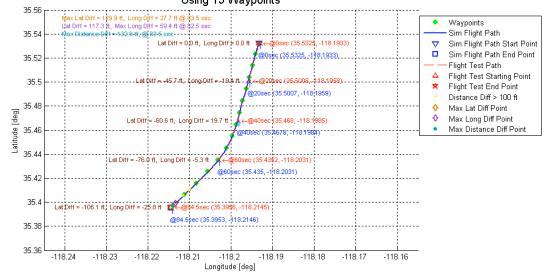


Generic G-III 3-D Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

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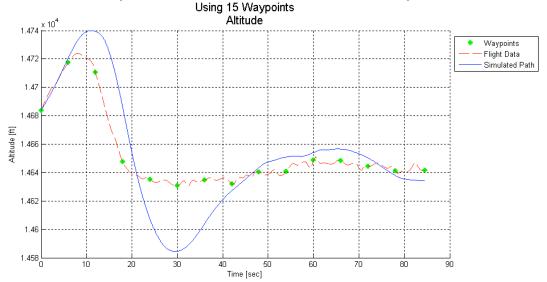


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

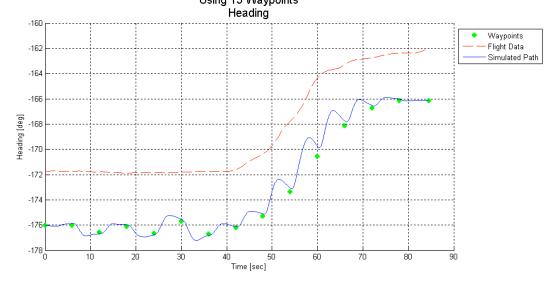


Generic G-III Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

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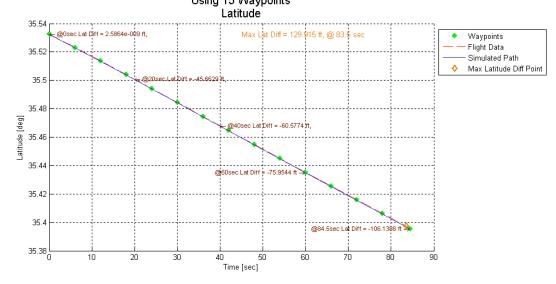


Generic G-III Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

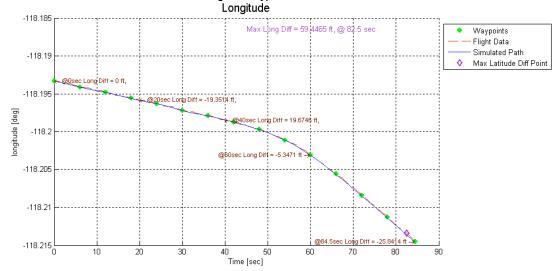


Generic G-III Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

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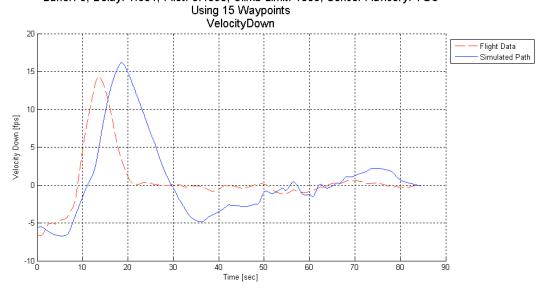


Generic G-III Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

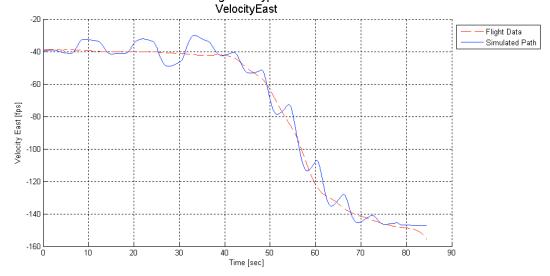


Generic G-III Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

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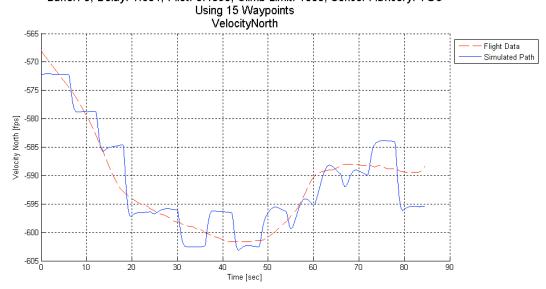


Generic G-III Time History Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude



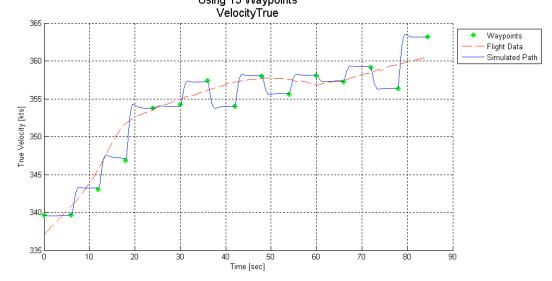
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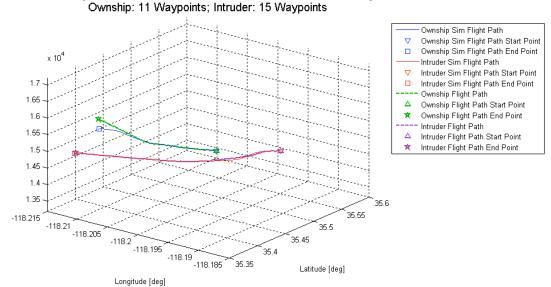
Generic G-III Time History Plot Flight No. 375 Run No. 2

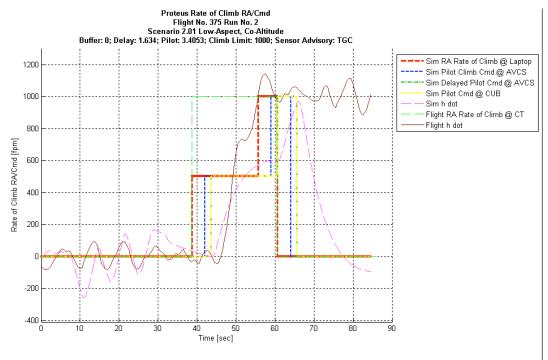
Scenario 2.01 Low-Aspect, Co-Altitude
Buffer: 0; Delay: 1.634; Pilot: 3.4053; Climb Limit: 1000; Sensor Advisory: TGC
Using 15 Waypoints

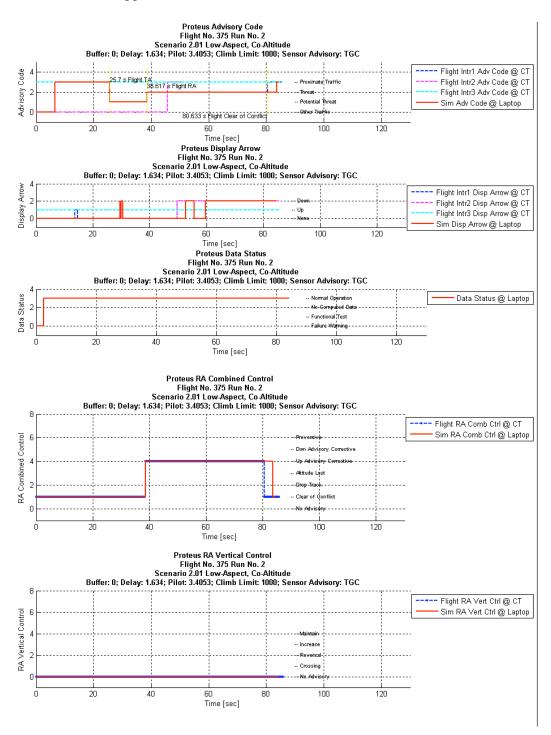


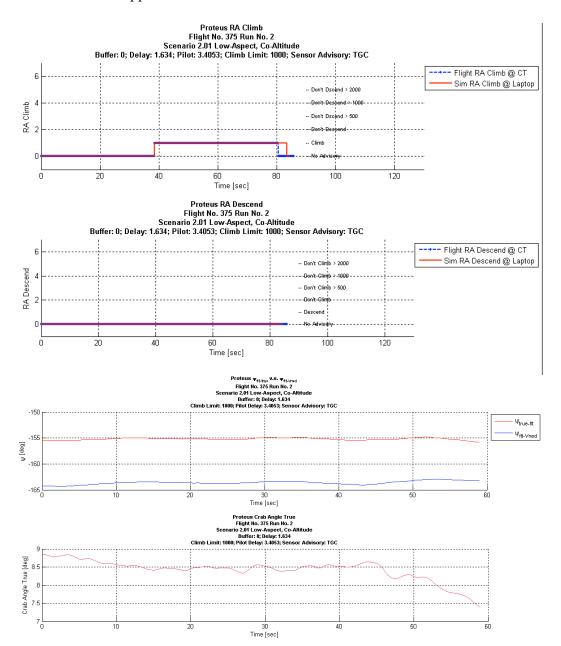
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 2 Scenario 2.01 Low-Aspect, Co-Altitude

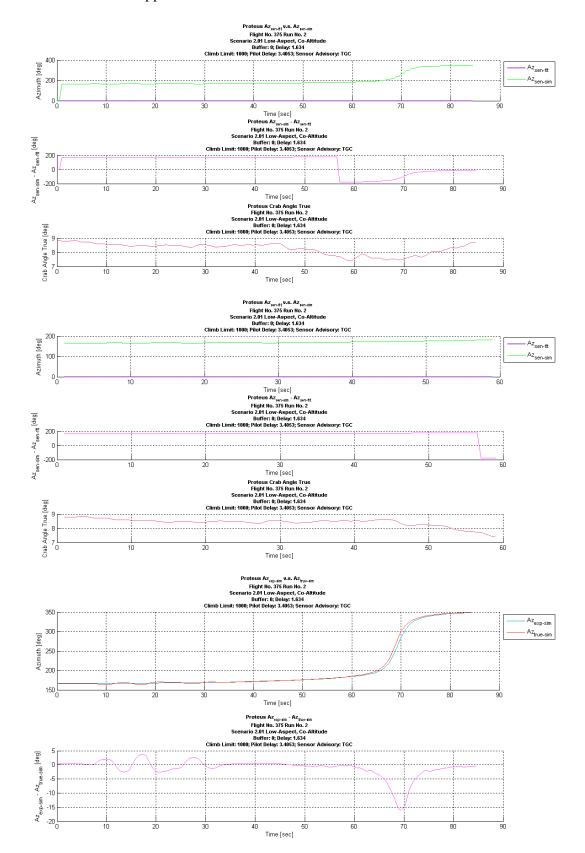
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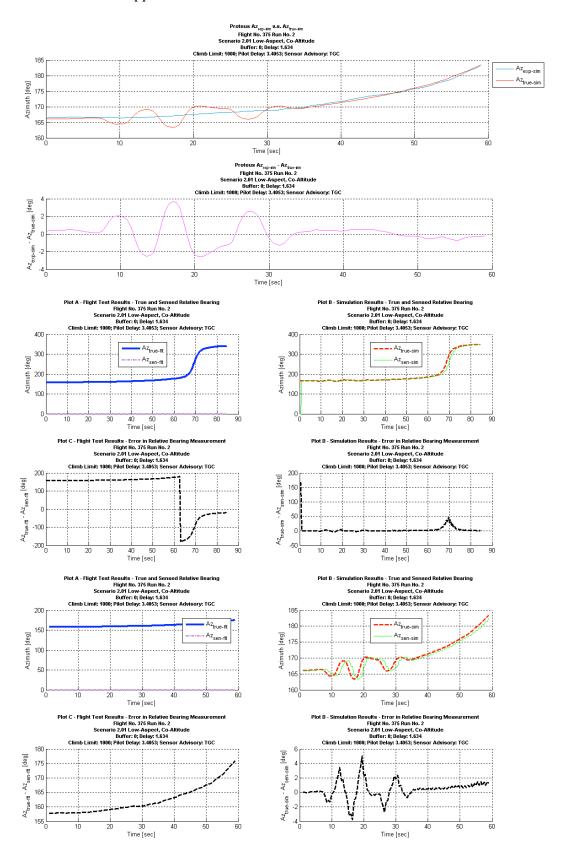


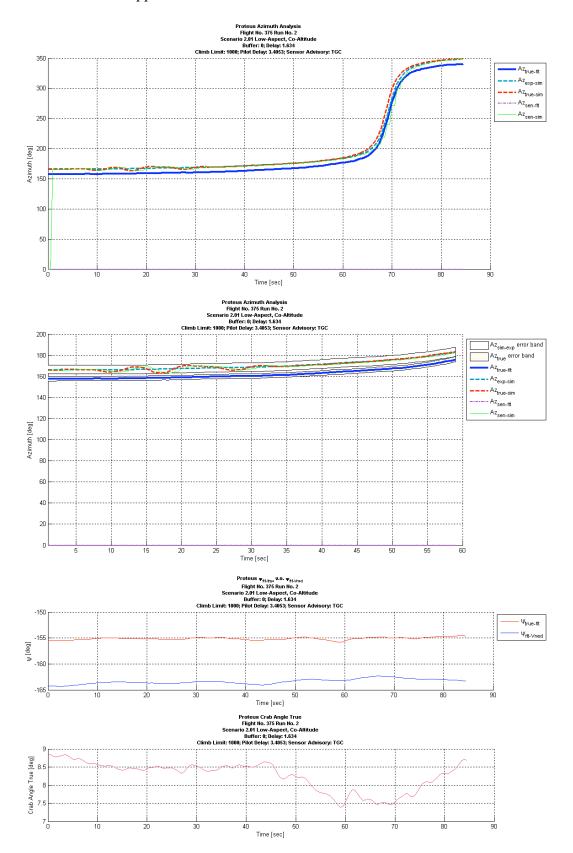


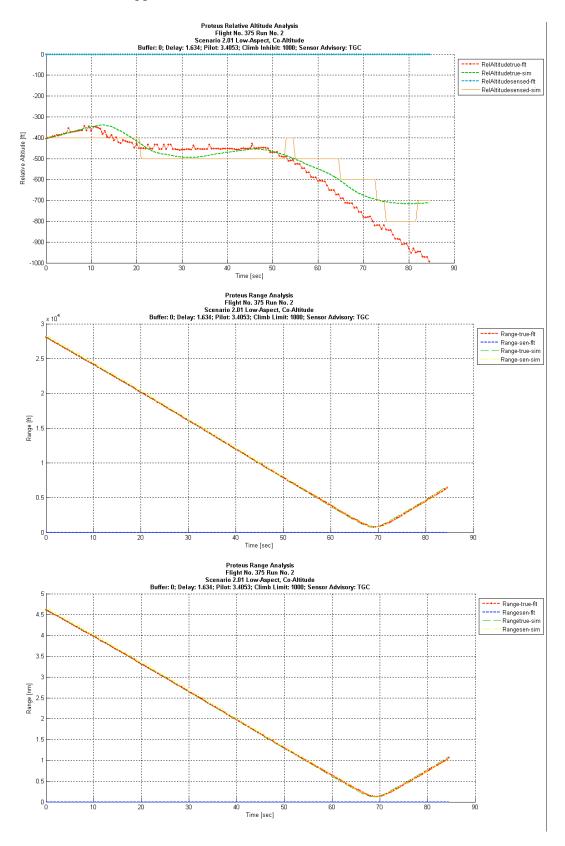






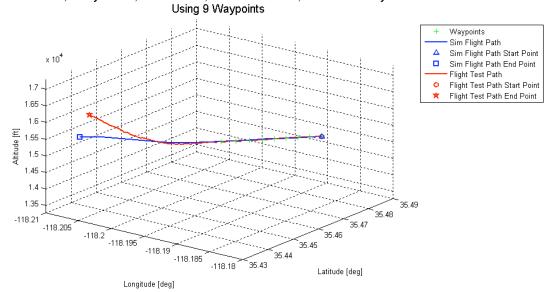






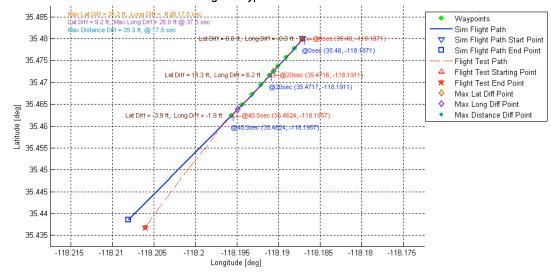
Flight 375 Run 4

Proteus 3-D Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude Buffer: 4; Delay: 1.634; Pilot: 5.5407; Climb Limit: 2500; Sensor Advisory: TGC



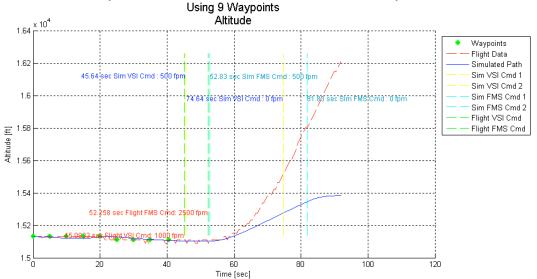
Proteus Flight Path Position Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.5407; Climb Limit: 2500; Sensor Advisory: TGC Using 9 Waypoints



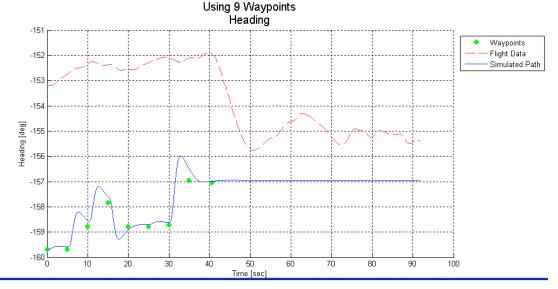
Proteus Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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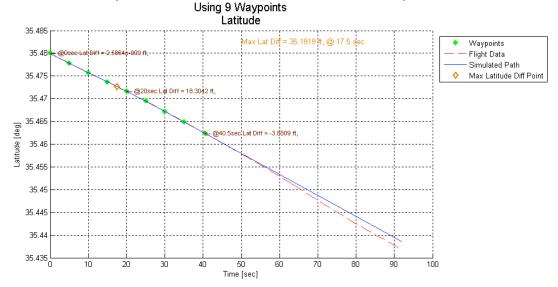
Proteus Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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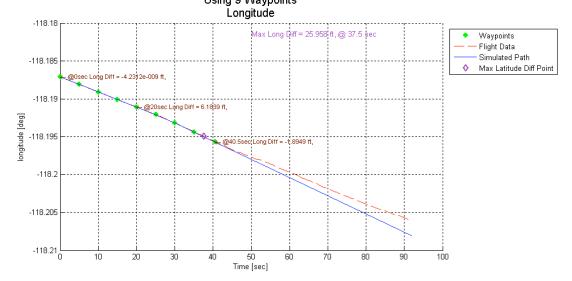
Proteus Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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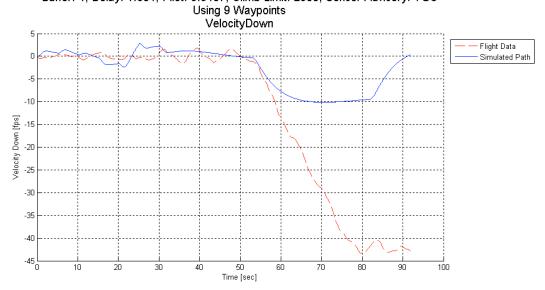
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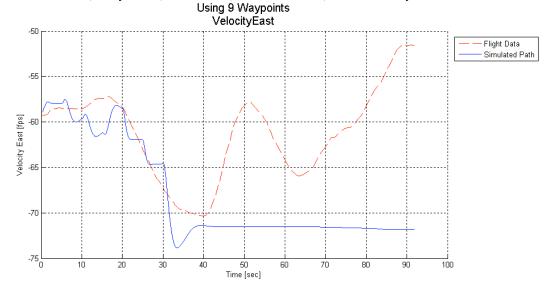
Proteus Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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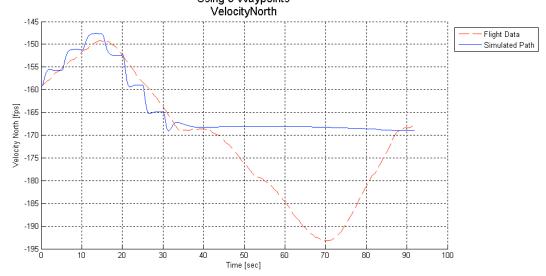
Proteus Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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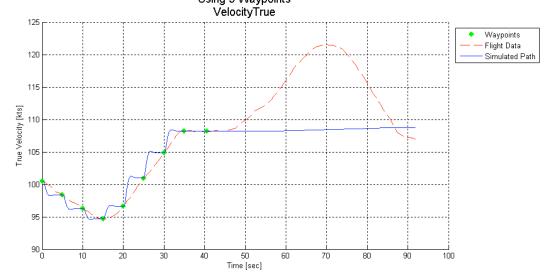
Proteus Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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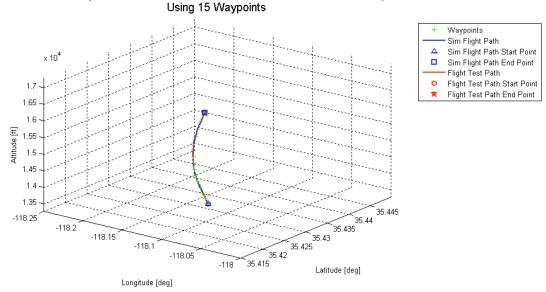
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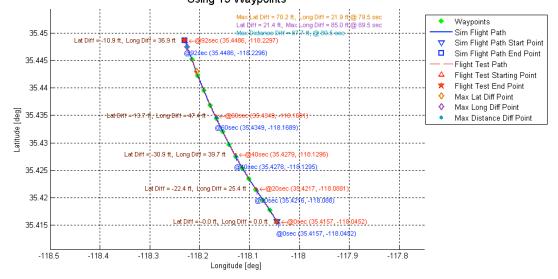
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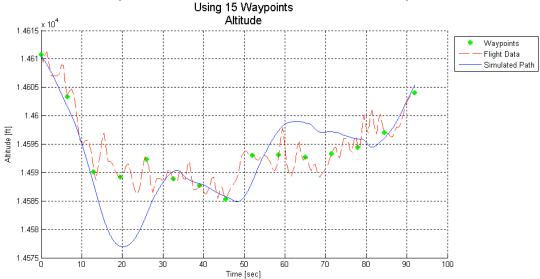
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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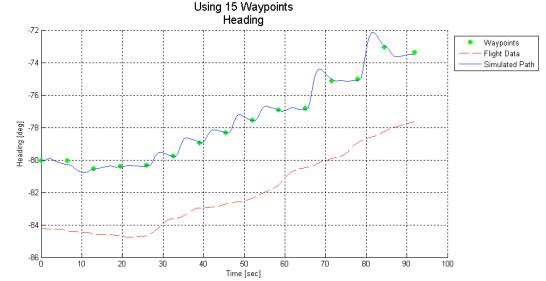
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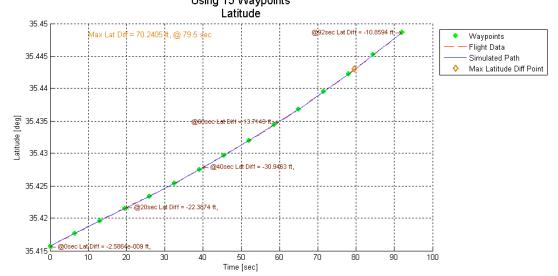
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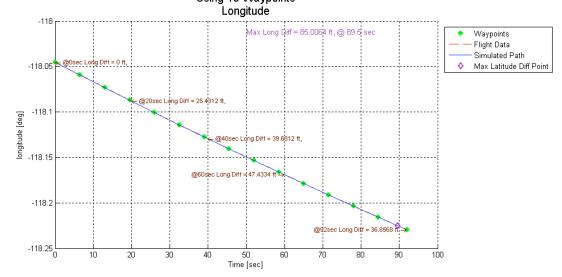
Generic G-III Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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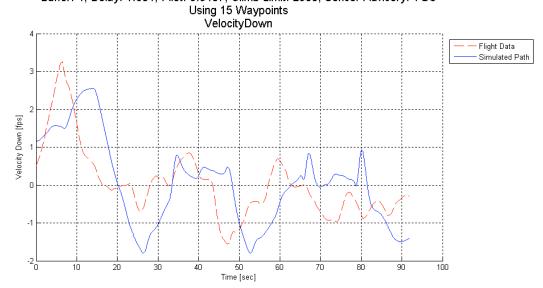
Generic G-III Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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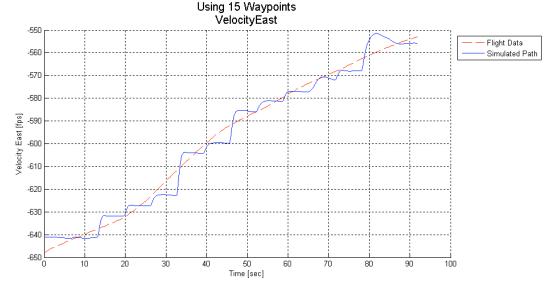
Generic G-III Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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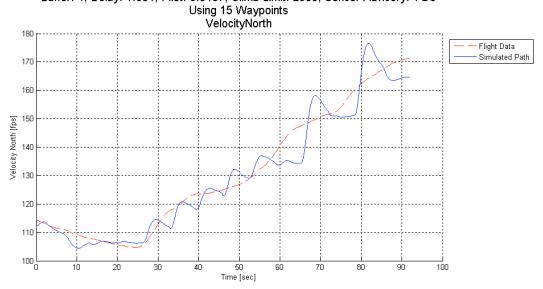
Generic G-III Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

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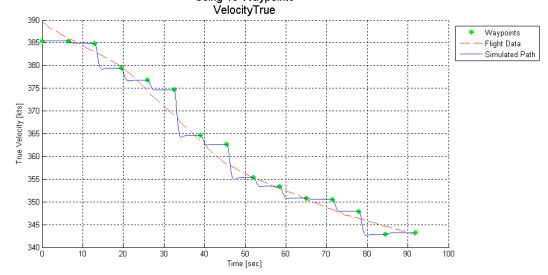
Generic G-III Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.5407; Climb Limit: 2500; Sensor Advisory: TGC



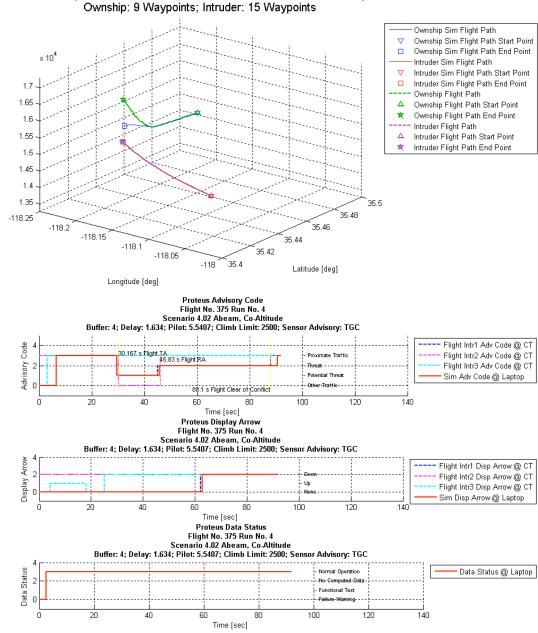
Generic G-III Time History Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

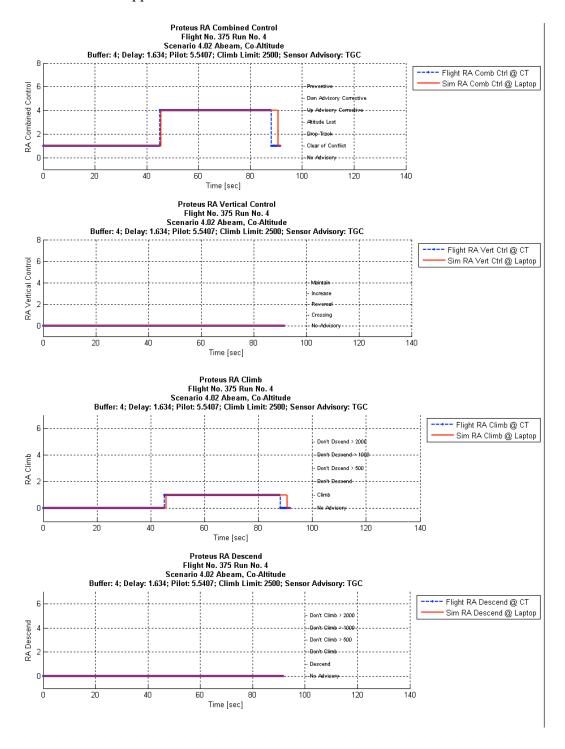
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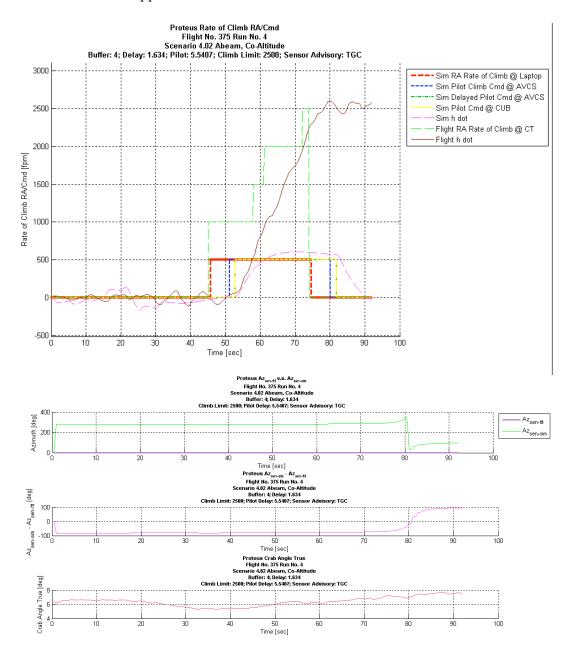


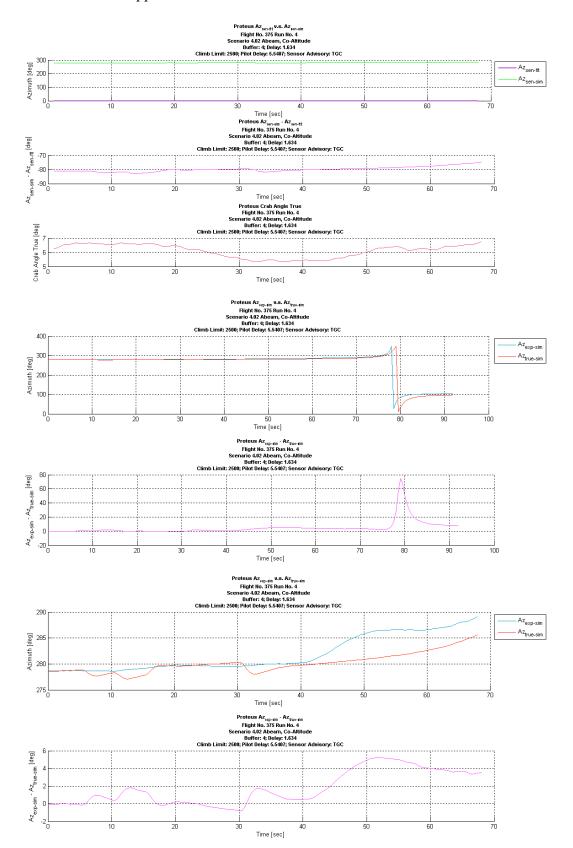
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 4 Scenario 4.02 Abeam, Co-Altitude

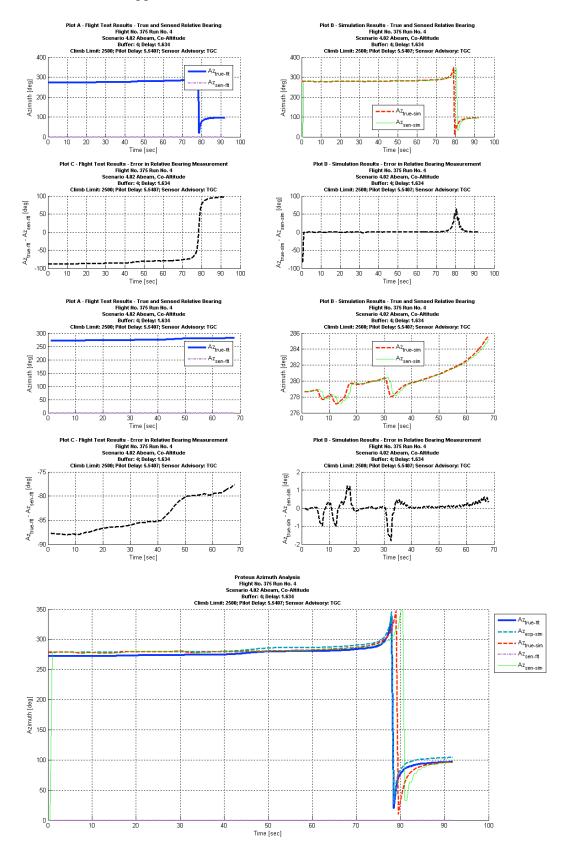
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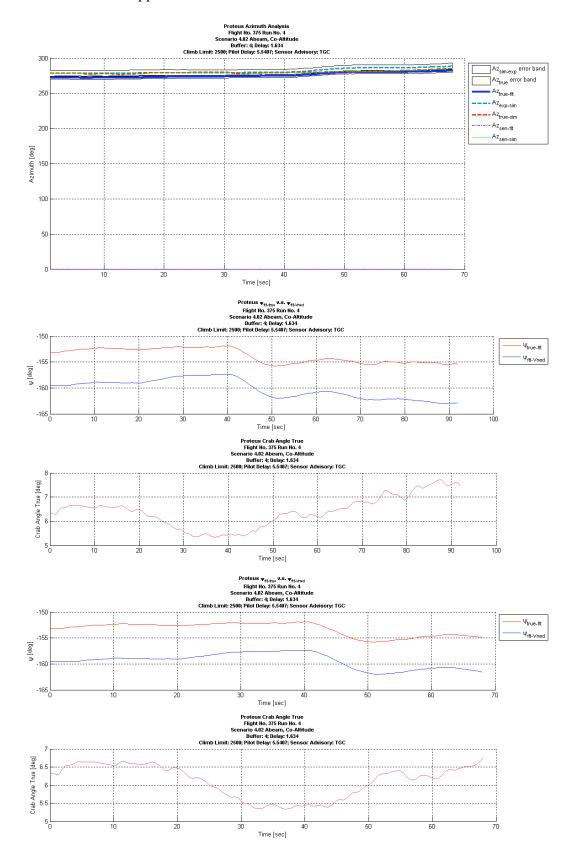


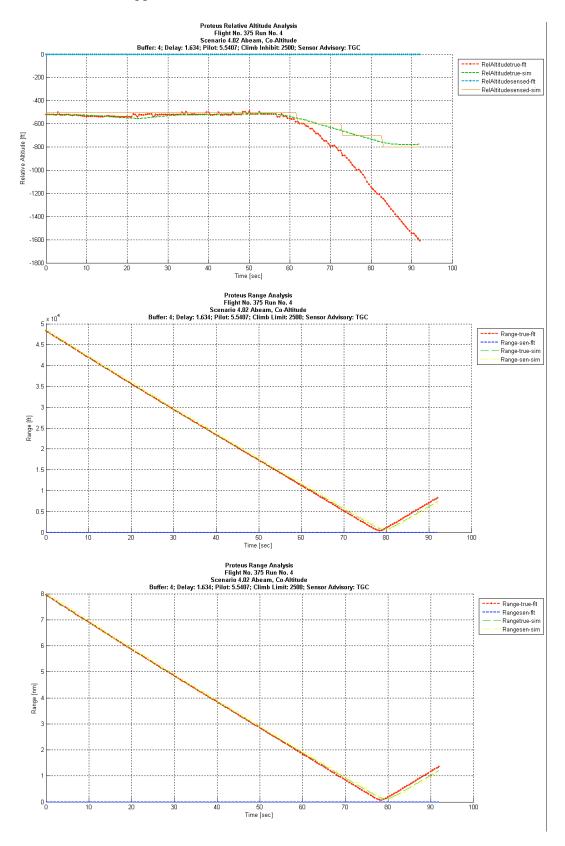








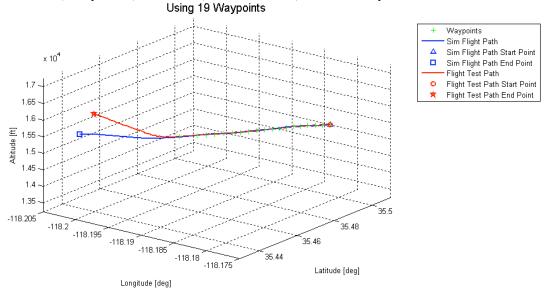




Flight 375 Run `

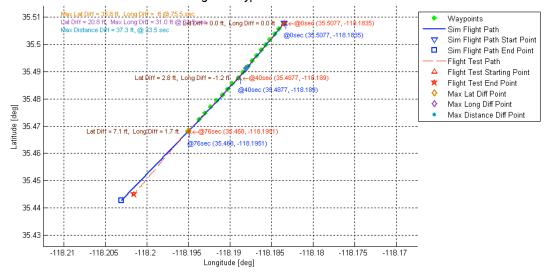
Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC

Proteus 3-D Plot



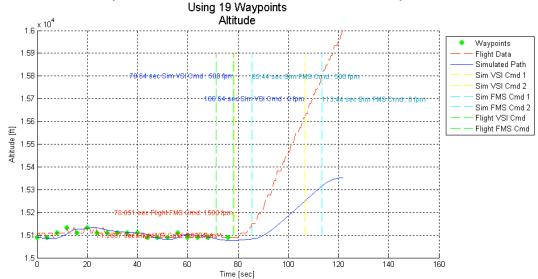
Proteus Flight Path Position Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



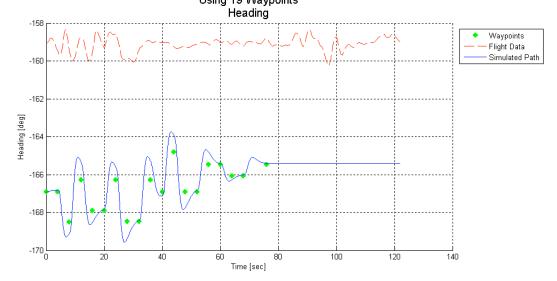
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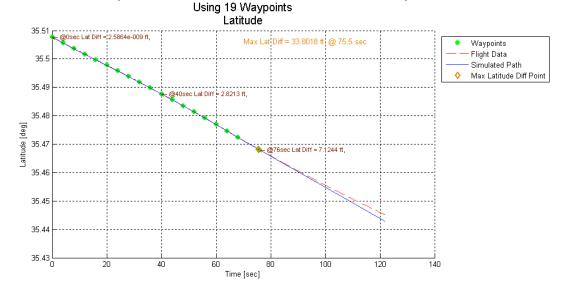
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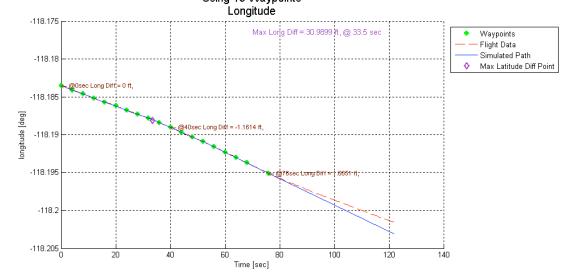
Proteus Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

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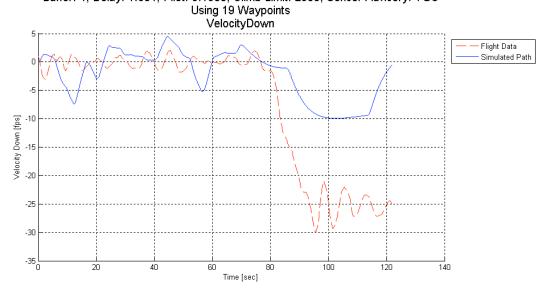
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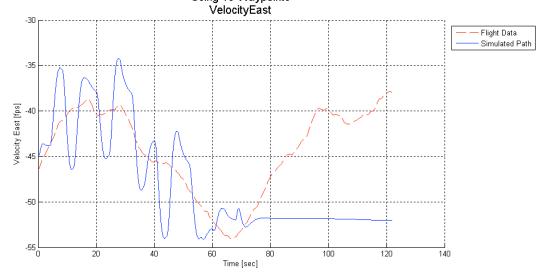
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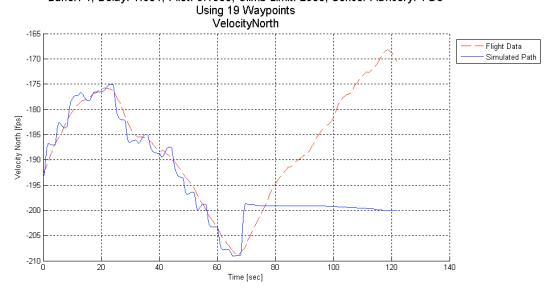
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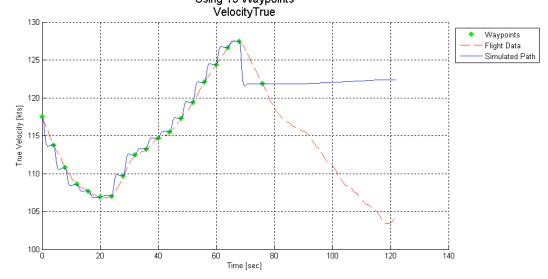
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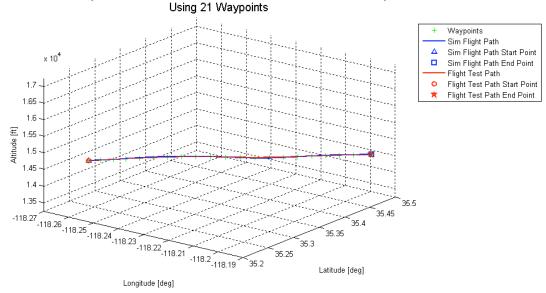
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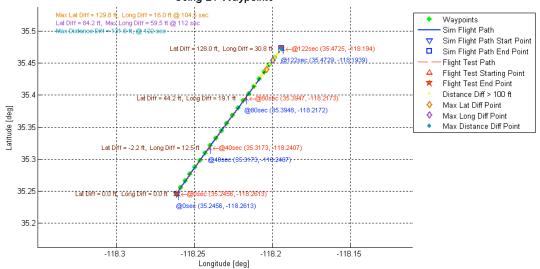
Generic G-III 3-D Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

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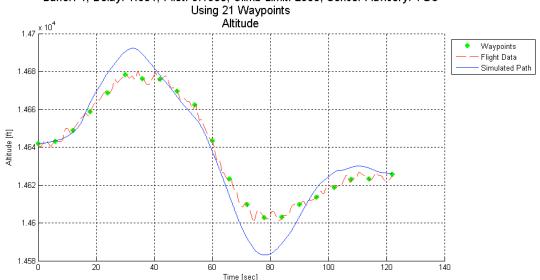
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

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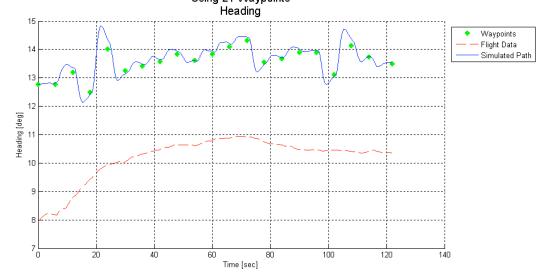
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Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC



Generic G-III Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC Using 21 Waypoints

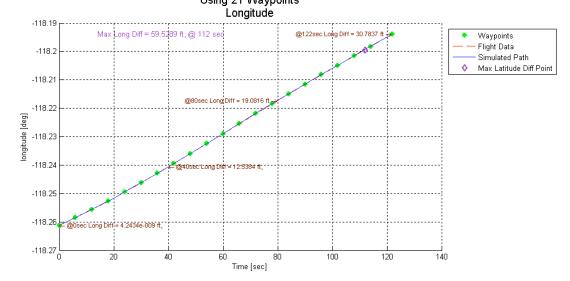


Generic G-III Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

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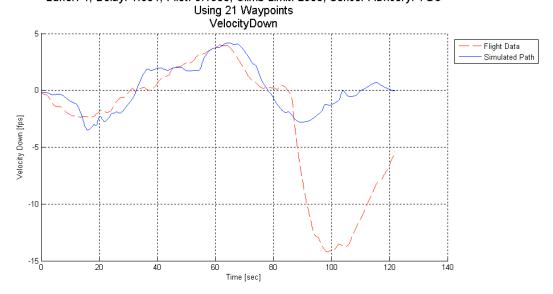
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Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC Using 21 Waypoints



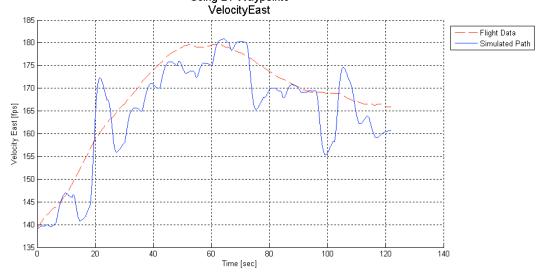
Generic G-III Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC



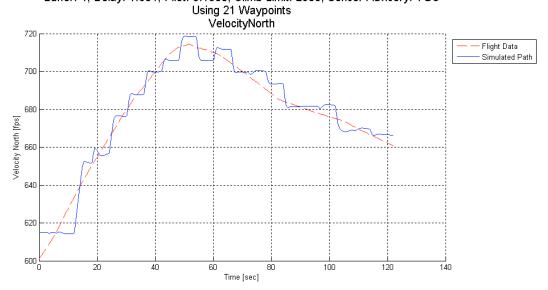
Generic G-III Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC Using 21 Waypoints



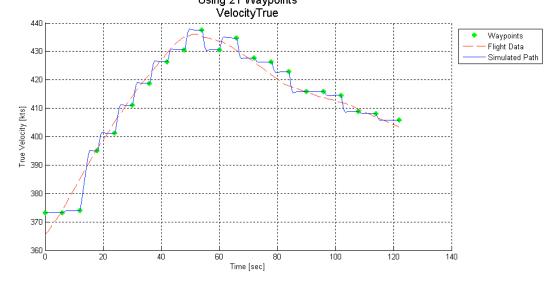
Generic G-III Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 5.1503; Climb Limit: 2500; Sensor Advisory: TGC



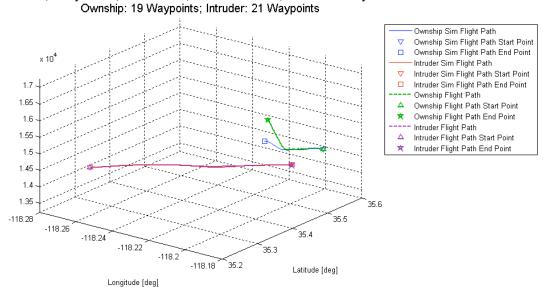
Generic G-III Time History Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

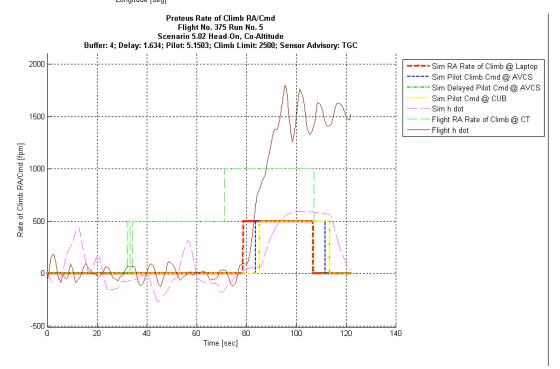
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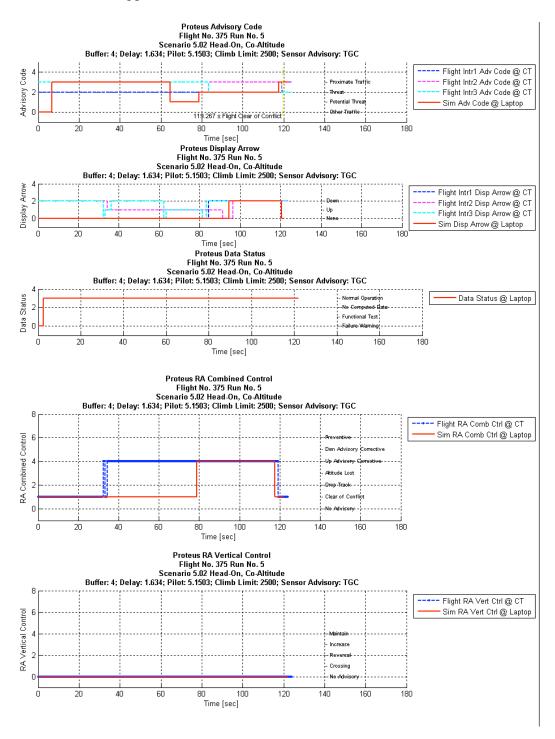


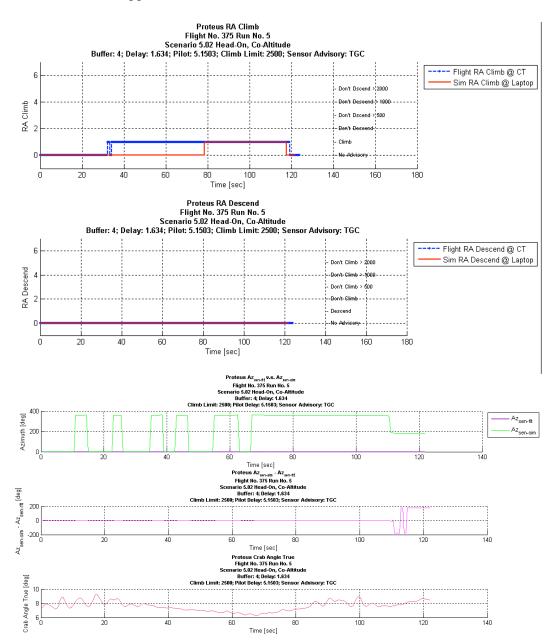
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 5 Scenario 5.02 Head-On, Co-Altitude

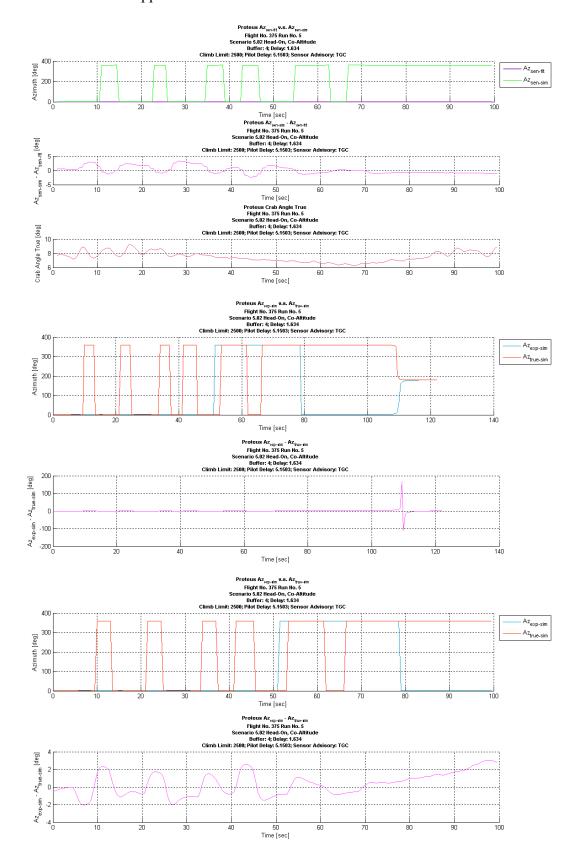
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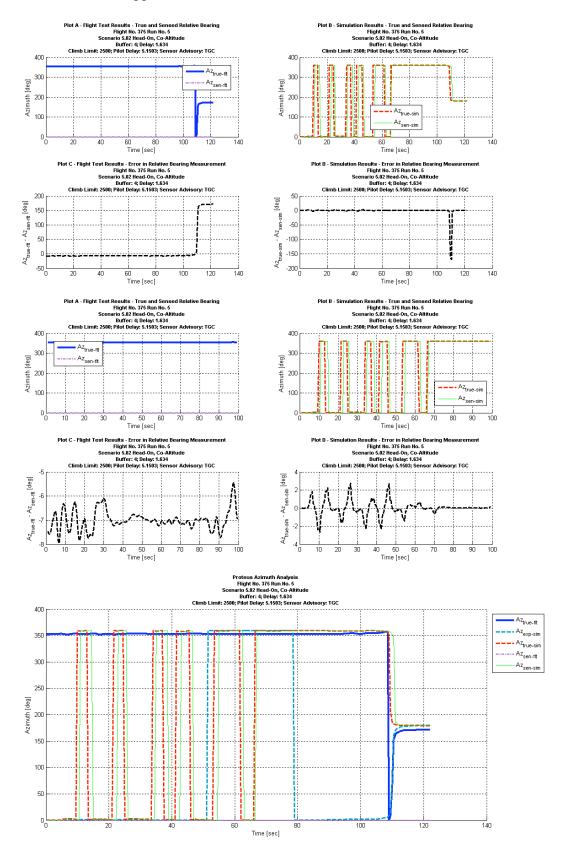


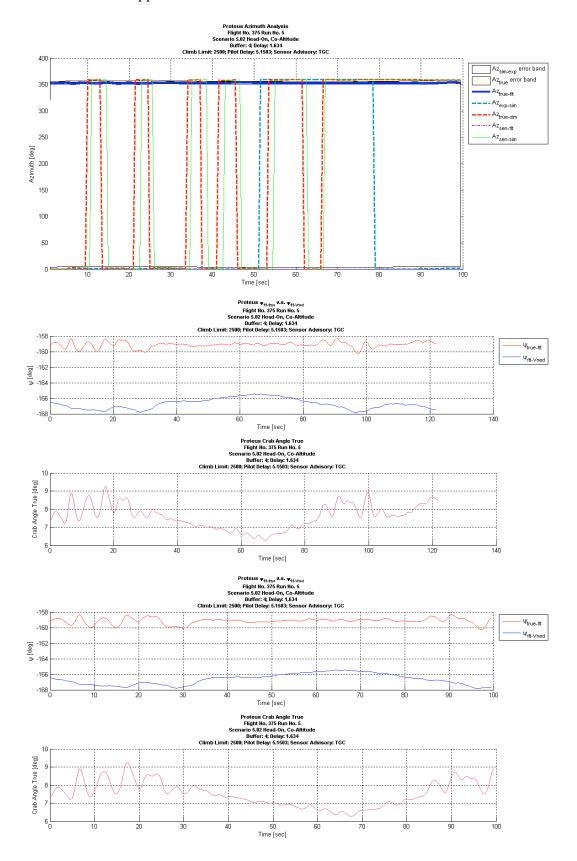


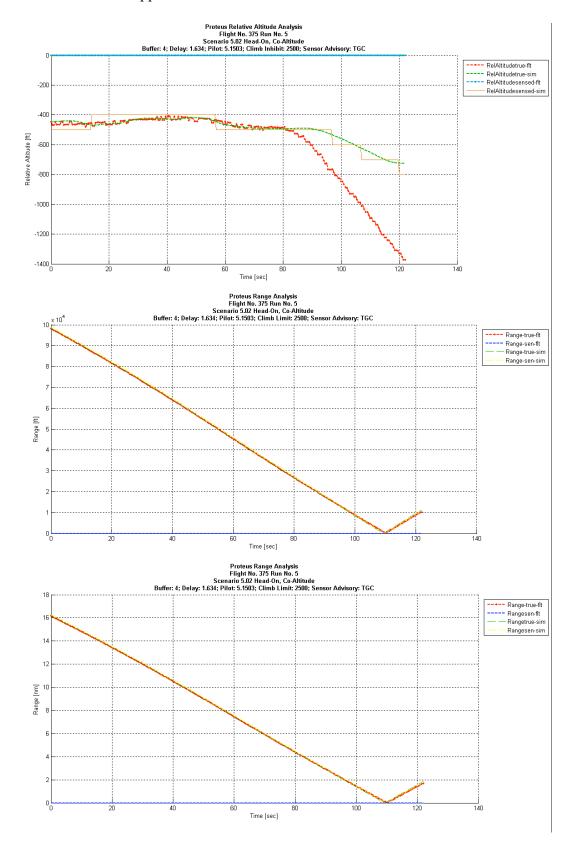








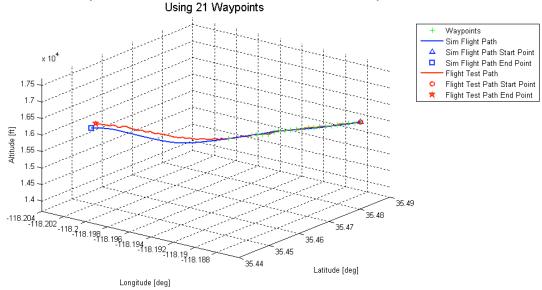




Flight 375 Run 6

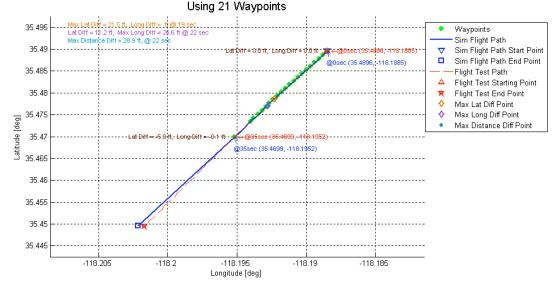
Proteus 3-D Plot
Flight No. 375 Run No. 6
Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC



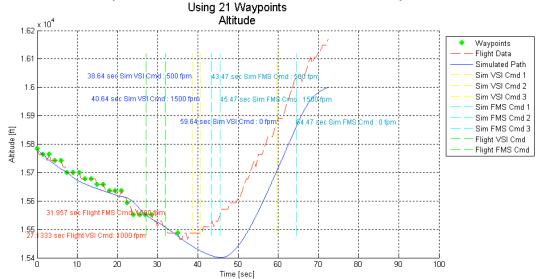
Proteus Flight Path Position Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

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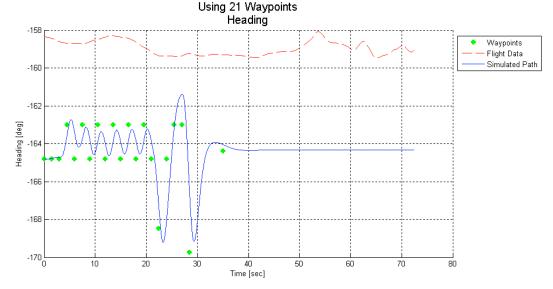
Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

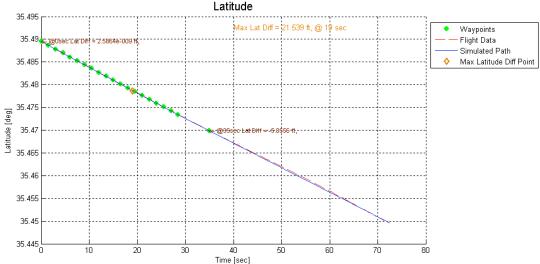
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Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC

Using 21 Waypoints



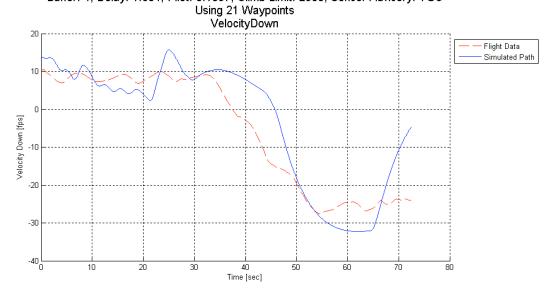
Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

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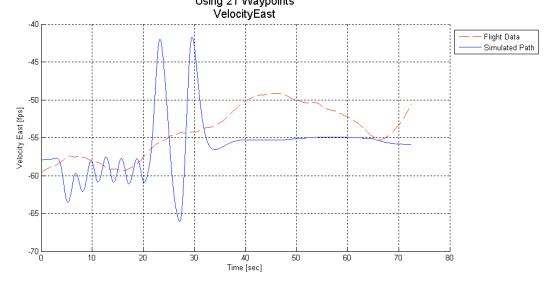
Longitude Waypoints Flight Data Simulated Path Max Latitude Diff Point -118.192 ongitude [deg] -118.194 -118.198 -118.202 -118.204 10 20 30 60 70 80 Time [sec]

Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC

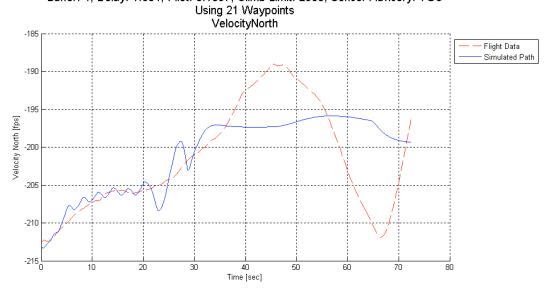


Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

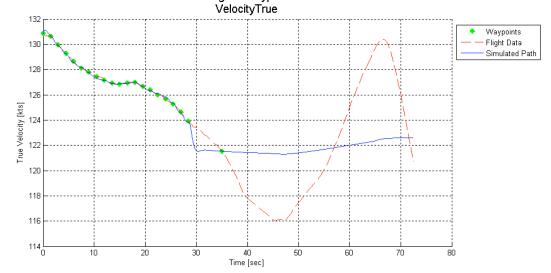


Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

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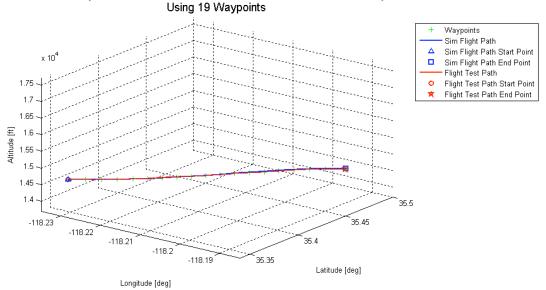


Proteus Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

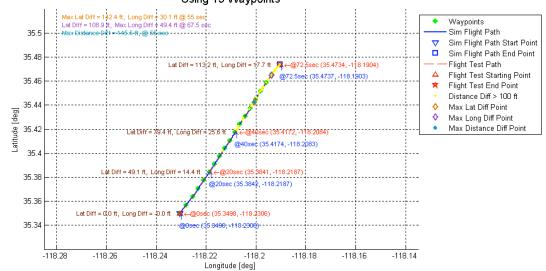


Generic G-III 3-D Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Inhibit: 2500; Sensor Advisory: TGC

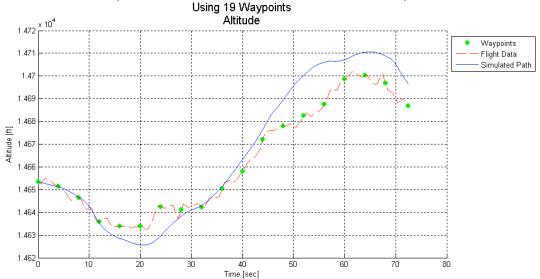


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

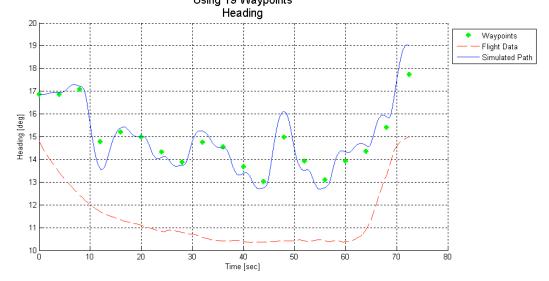


Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC



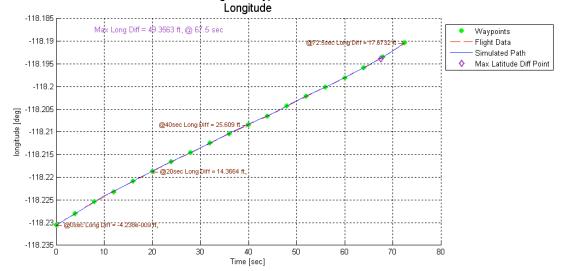
Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending



Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

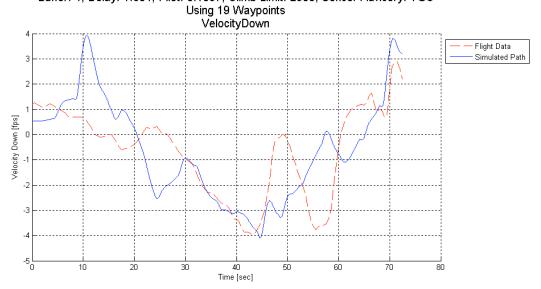
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> Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending



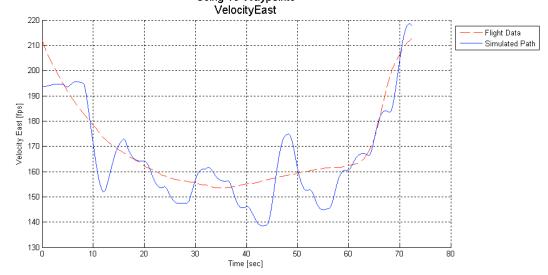
Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC



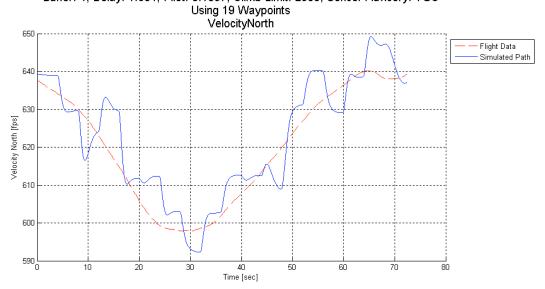
Generic G-III Time History Plot Flight No. 375 Run No. 6

Scenario 6.02 Head-On, Host Descending
Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC
Using 19 Waypoints

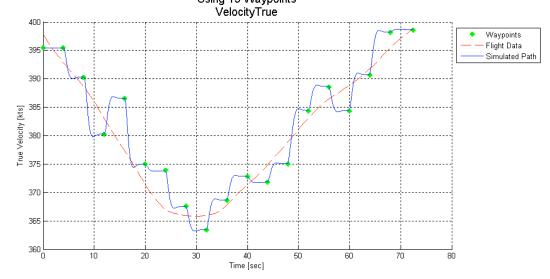


Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 3.1897; Climb Limit: 2500; Sensor Advisory: TGC



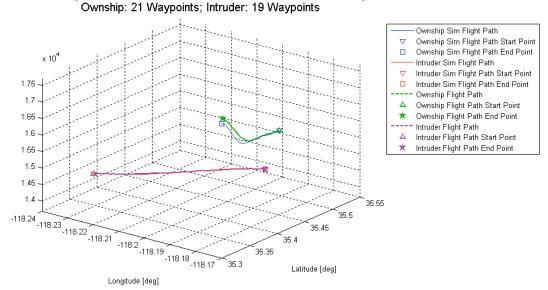
Generic G-III Time History Plot Flight No. 375 Run No. 6 Scenario 6.02 Head-On, Host Descending

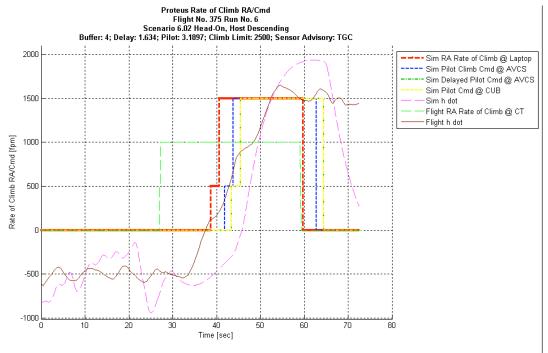


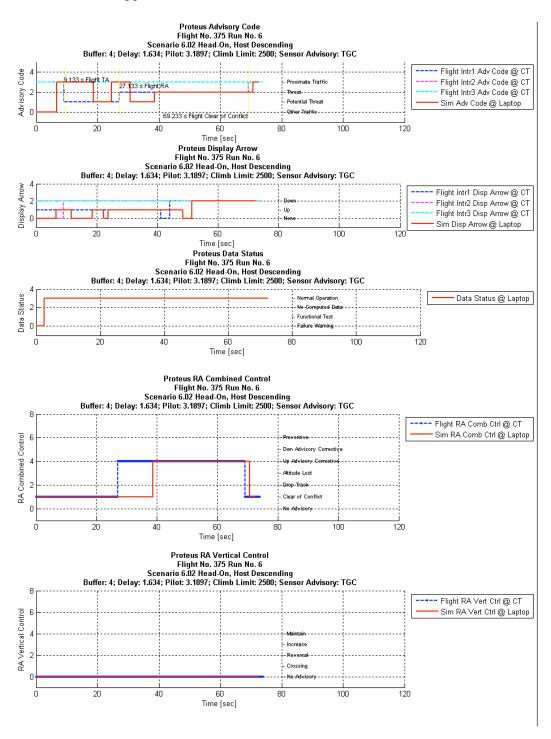
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 6

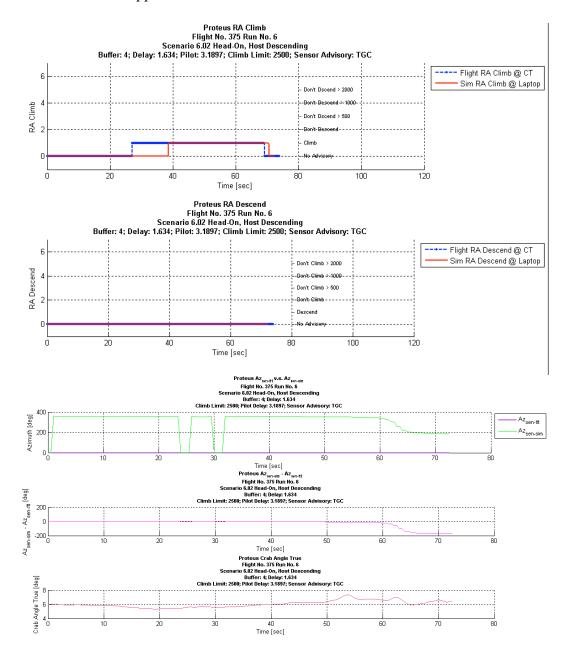
Scenario 6.02 Head-On, Host Descending

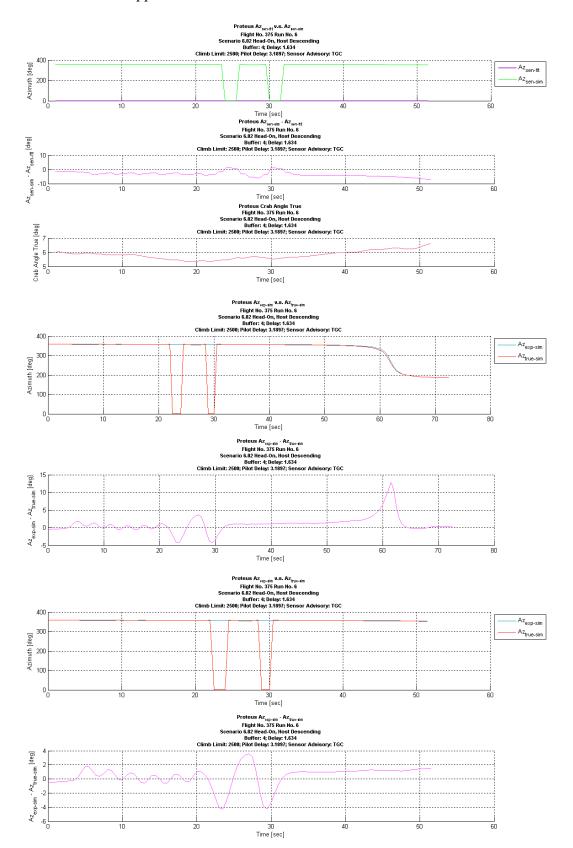
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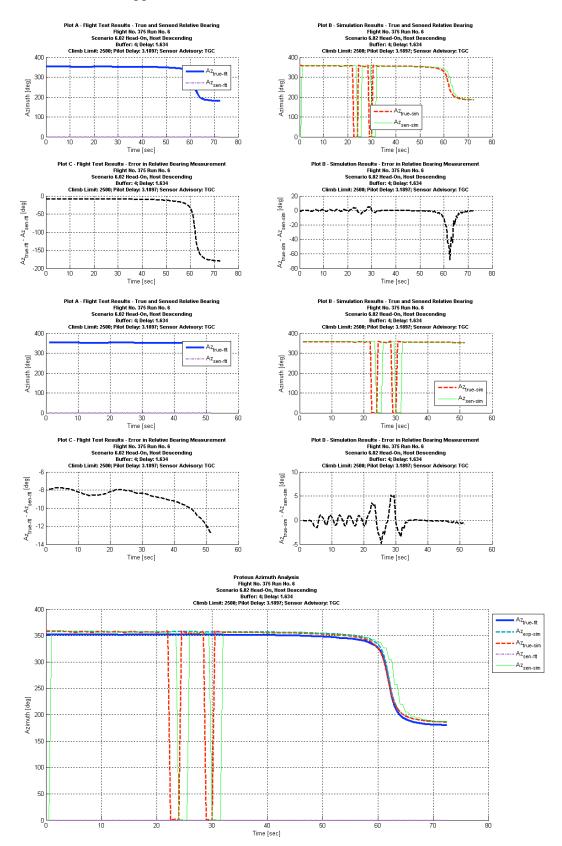


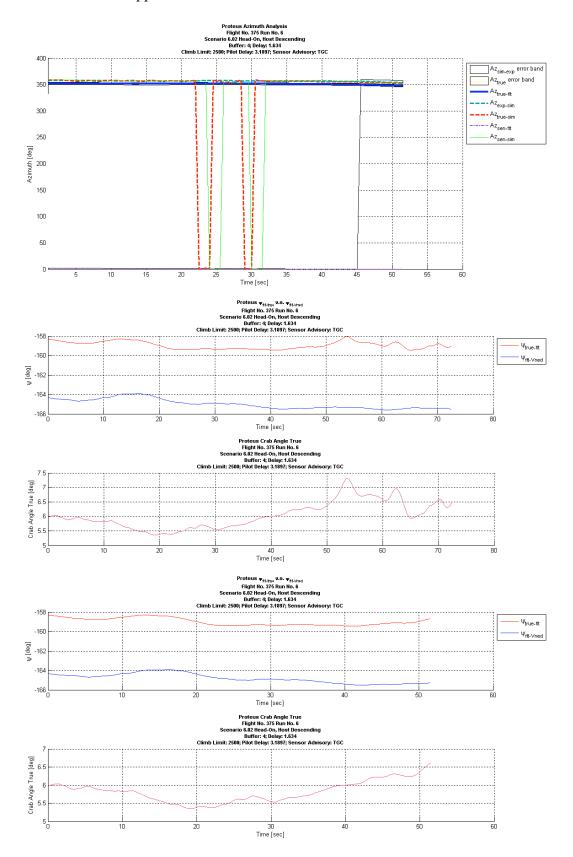


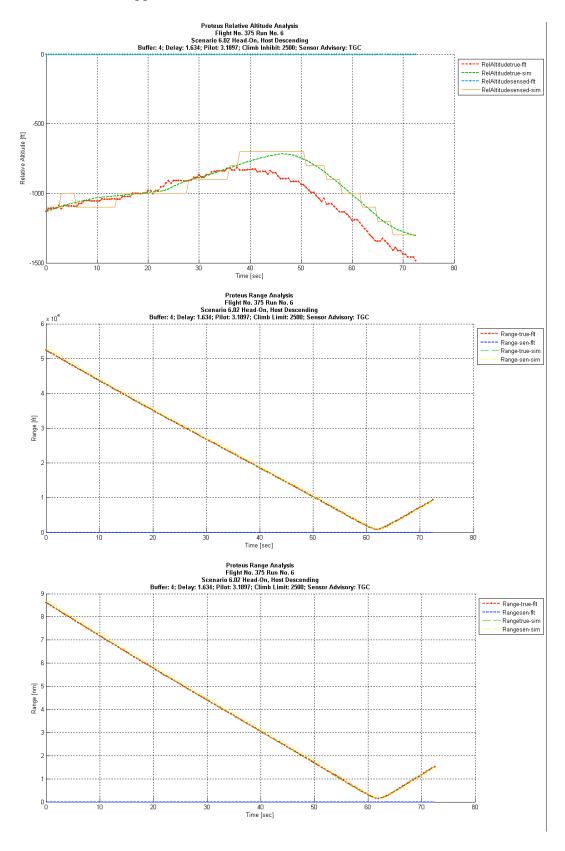








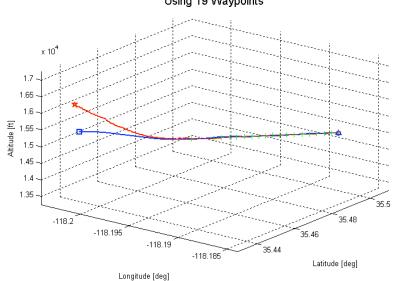




Flight 375 Run 7

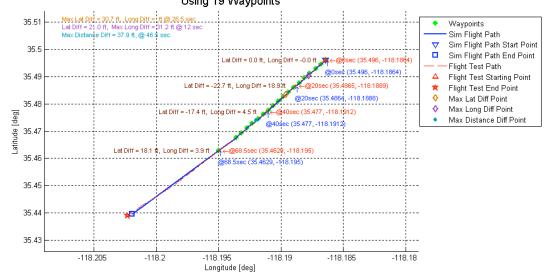
Proteus 3-D Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



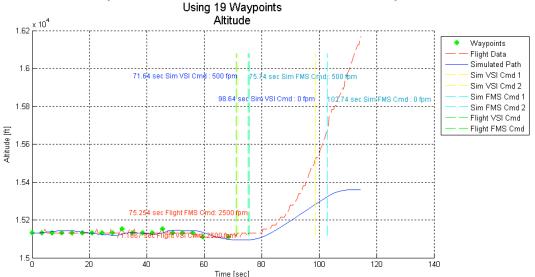
+ Waypoints
Sim Flight Path
△ Sim Flight Path Start Point
□ Sim Flight Path End Point
Flight Test Path
○ Flight Test Path Start Point
★ Flight Test Path End Point

Proteus Flight Path Position Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude



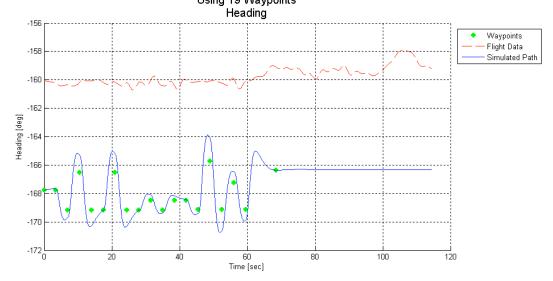
Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC



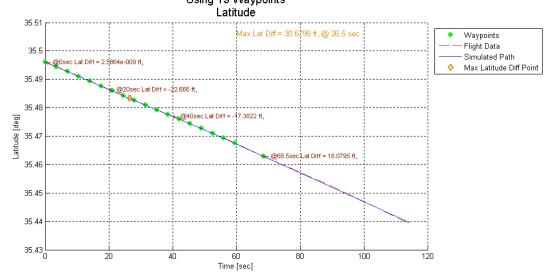
Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints

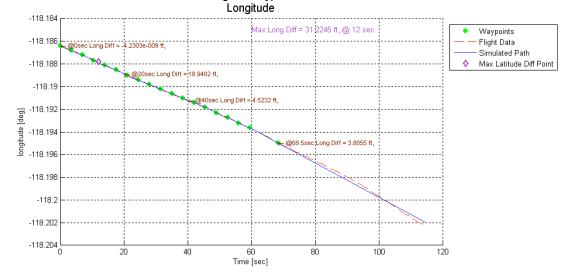


Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints

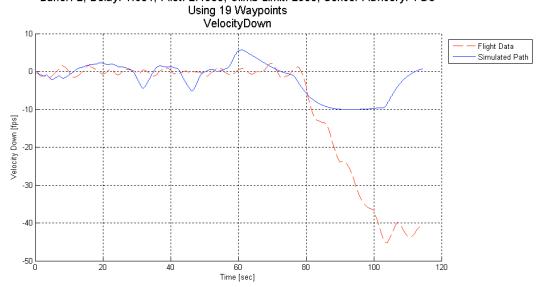


Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

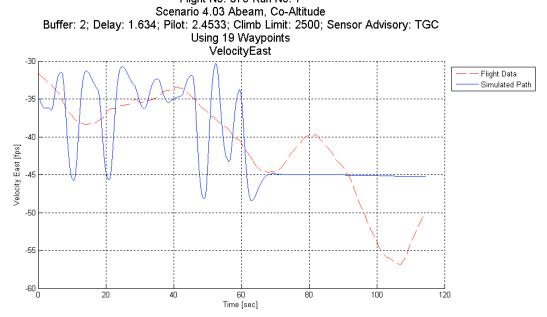


Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC

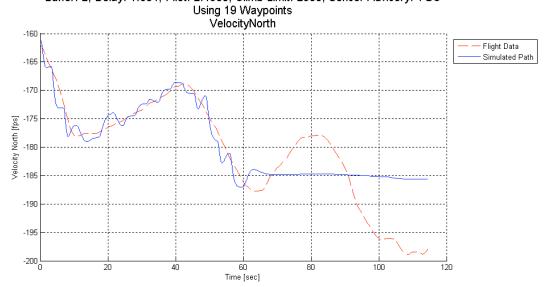


Proteus Time History Plot Flight No. 375 Run No. 7

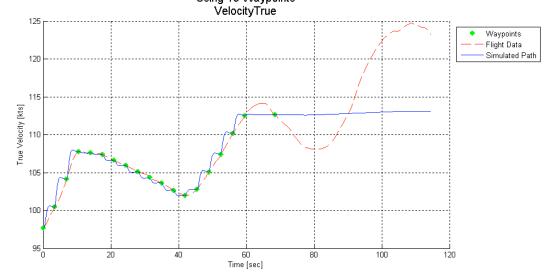


Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC

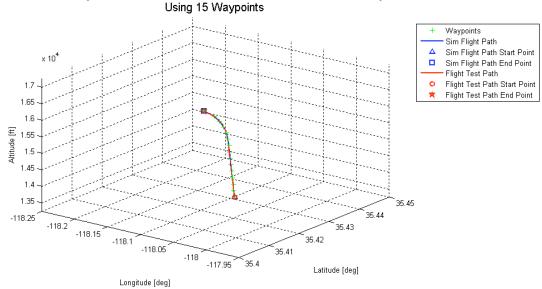


Proteus Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

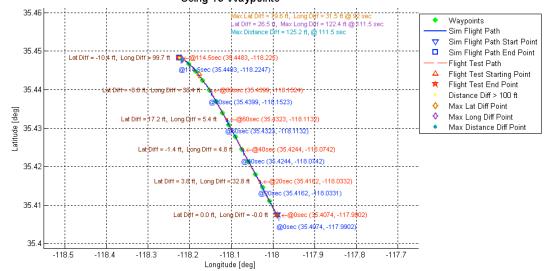


Generic G-III 3-D Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Inhibit: 2500; Sensor Advisory: TGC

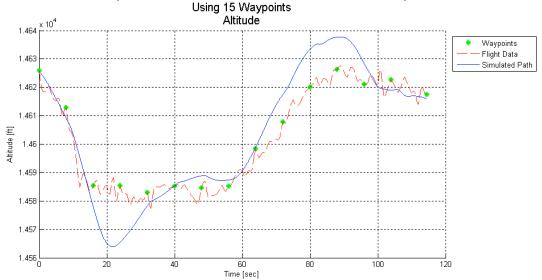


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

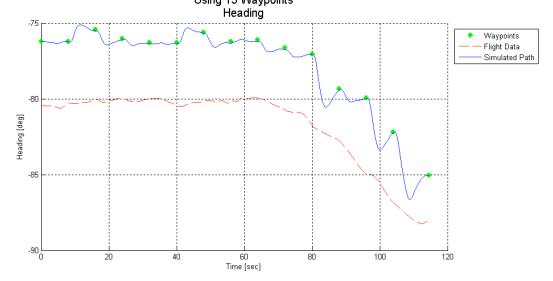


Generic G-III Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC

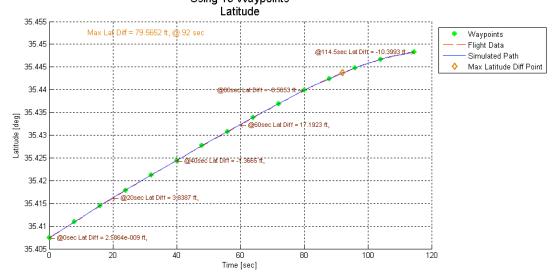


Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints

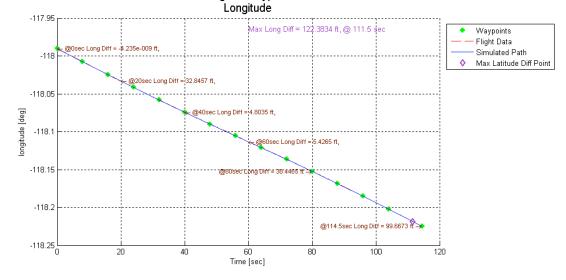


Generic G-III Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints

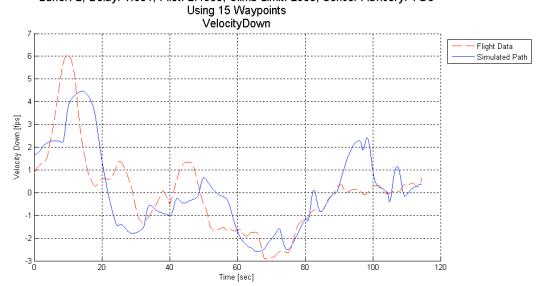


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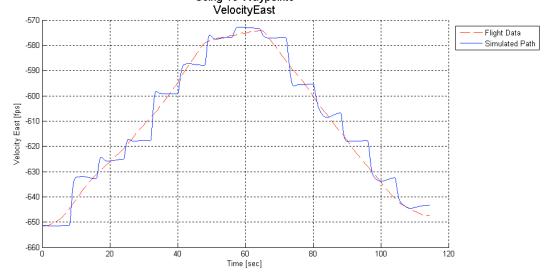


Generic G-III Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC

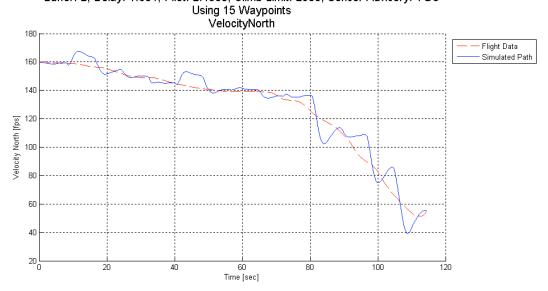


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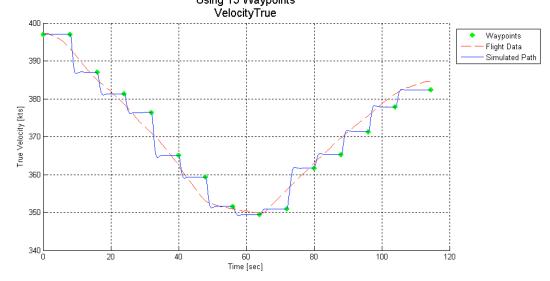


Generic G-III Time History Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

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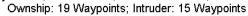


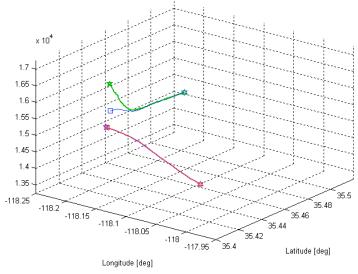
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Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 7 Scenario 4.03 Abeam, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.4533; Climb Limit: 2500; Sensor Advisory: TGC





Ownship Sim Flight Path

Ownship Sim Flight Path Start Point

Ownship Sim Flight Path End Point

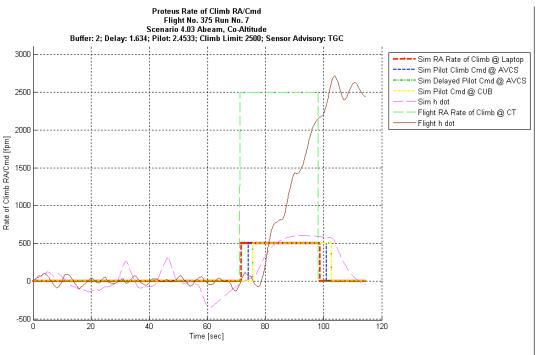
Intruder Sim Flight Path

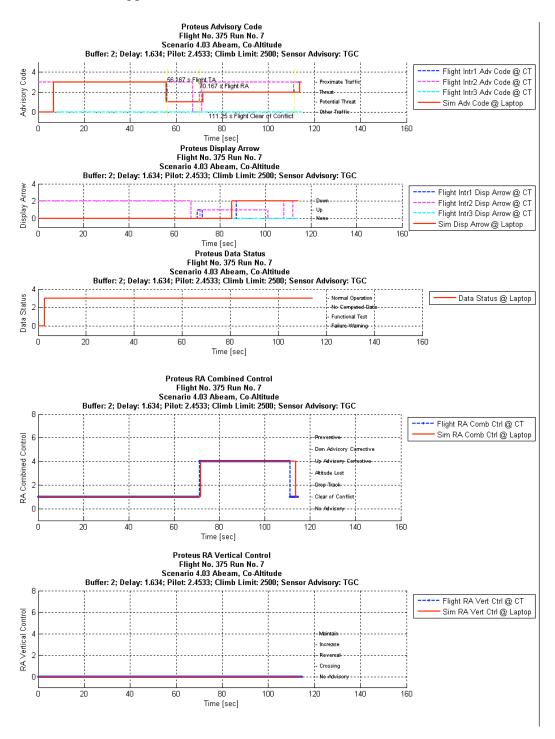
Intruder Sim Flight Path Start Point

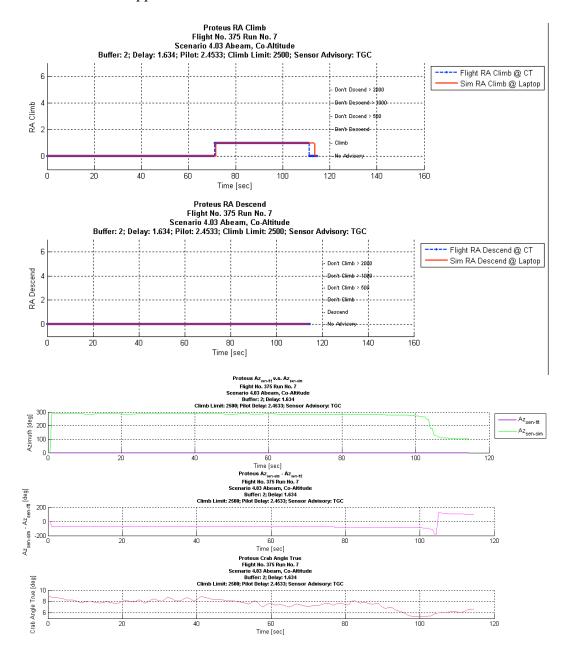
- Intruder Sim Flight Path Start Point
 Intruder Sim Flight Path End Point
 Ownship Flight Path
- △ Ownship Flight Path Start Point

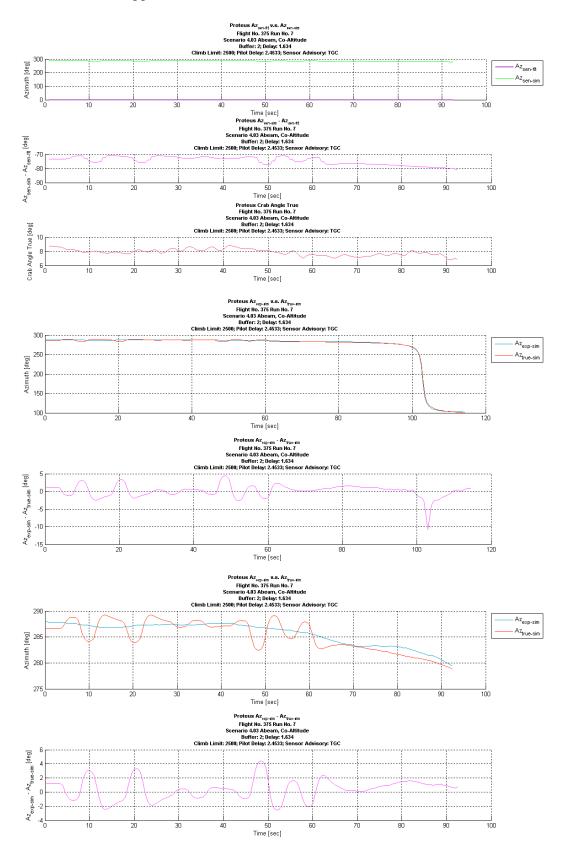
 ★ Ownship Flight Path End Point
- Intruder Flight Path

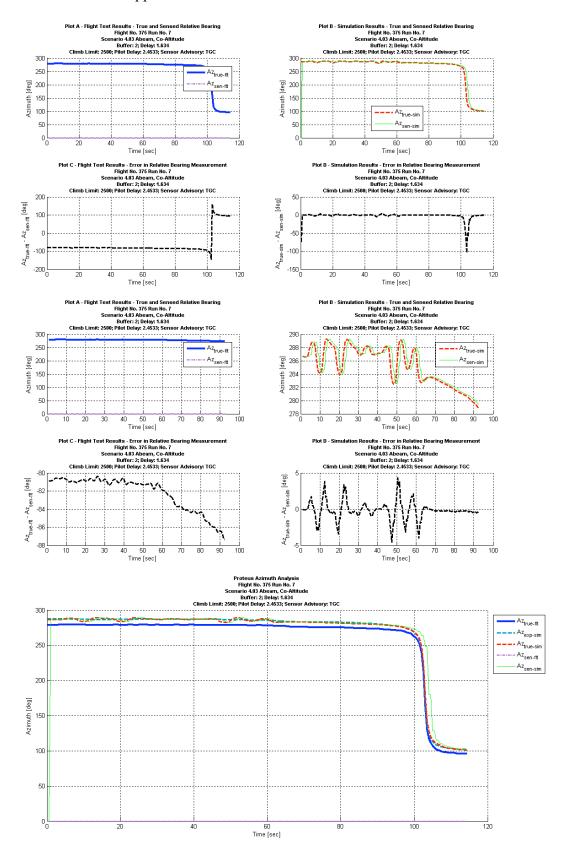
 Intruder Flight Path Start Point
- ★ Intruder Flight Path End Point

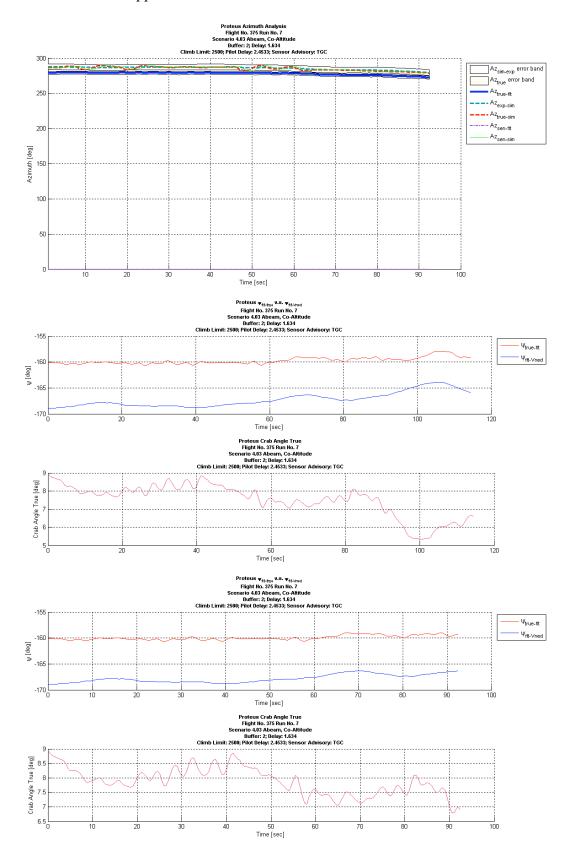


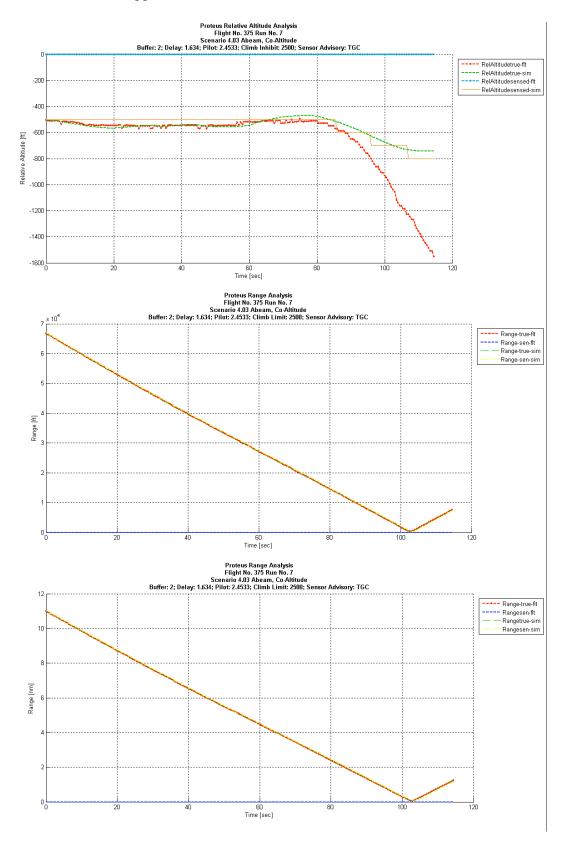










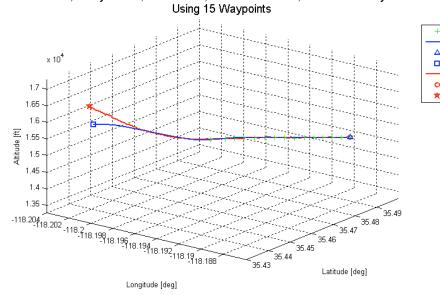


Flight 375 Run 9

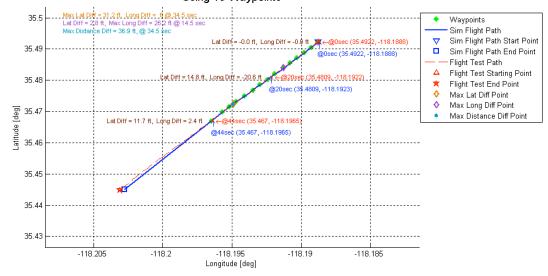
Waypoints
Sim Flight Path
Sim Flight Path Start Point
Sim Flight Path End Point
Flight Test Path
Flight Test Path
Flight Test Path Start Point
Flight Test Path End Point

Proteus 3-D Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

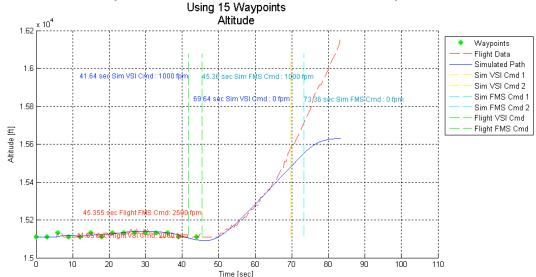


Proteus Flight Path Position Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude



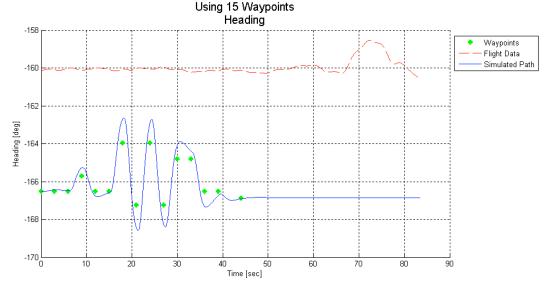
Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

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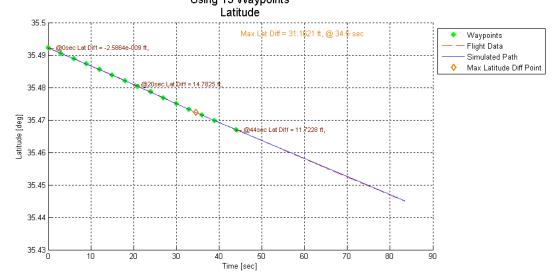
Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

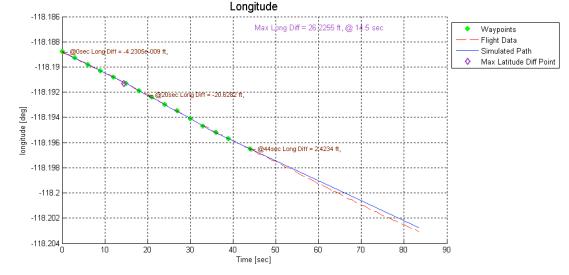


Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints



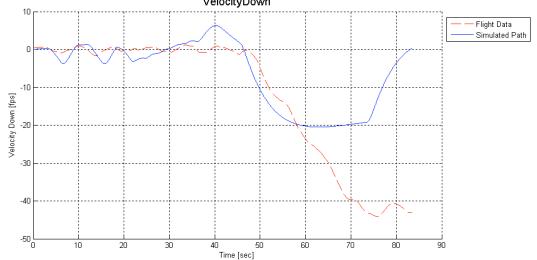
Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude



Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

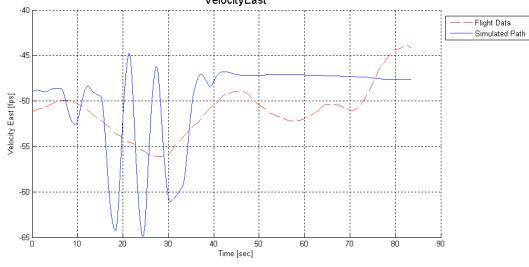
Using 15 Waypoints VelocityDown



Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

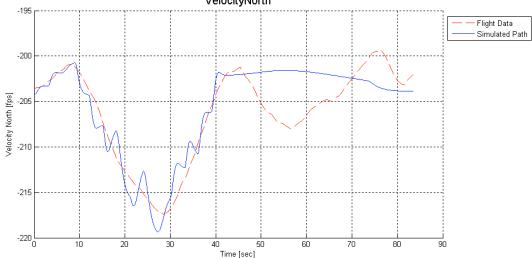
Using 15 Waypoints VelocityEast



Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

Using 15 Waypoints VelocityNorth



Proteus Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints

VelocityTrue

* Waypoints
— Flight Data
— Simulated Path

132

126

124

122

120

10

20

30

40

50

60

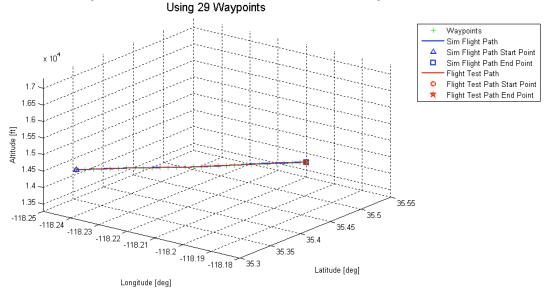
70

80

90

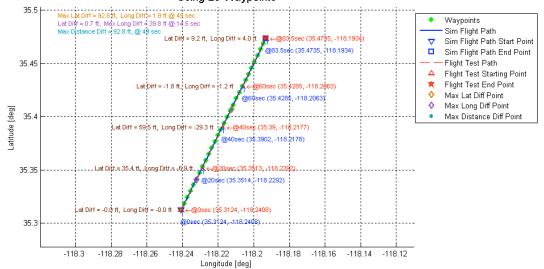
Generic G-III 3-D Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Inhibit: 2500; Sensor Advisory: TGC



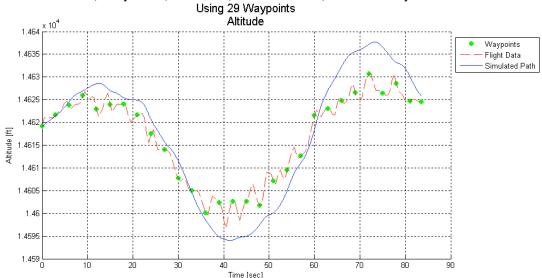
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC Using 29 Waypoints

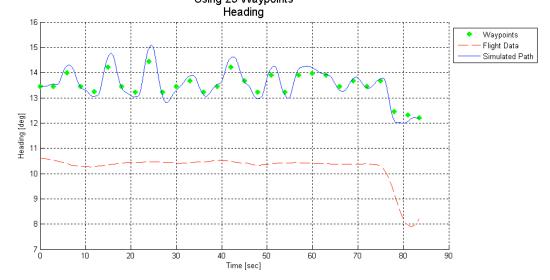


Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

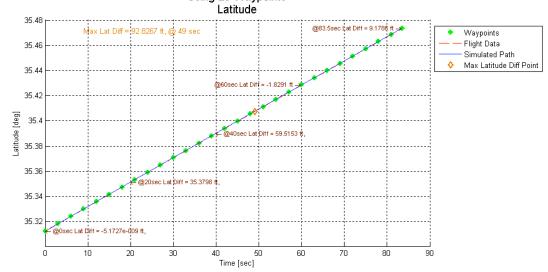


Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

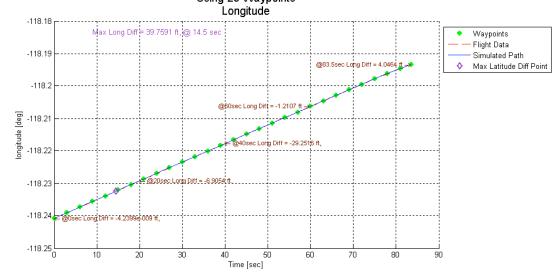


Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC Using 29 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude



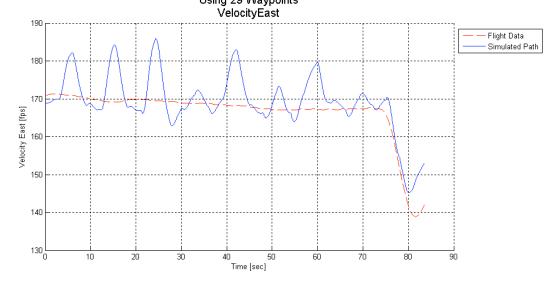
Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

Using 29 Waypoints
VelocityDown

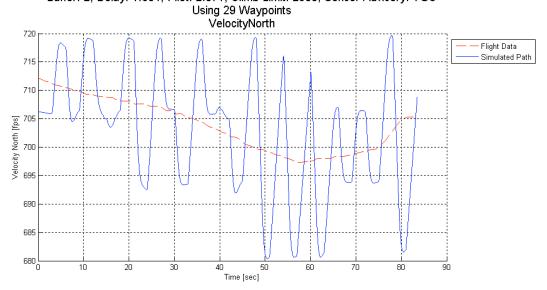
Flight Data
Simulated Path

Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

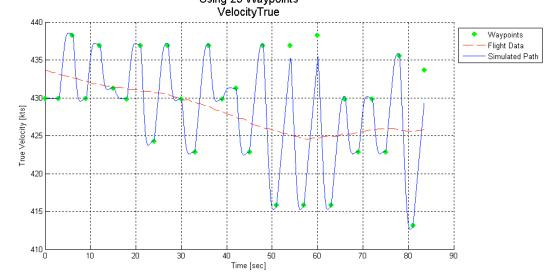


Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 2.071; Climb Limit: 2500; Sensor Advisory: TGC

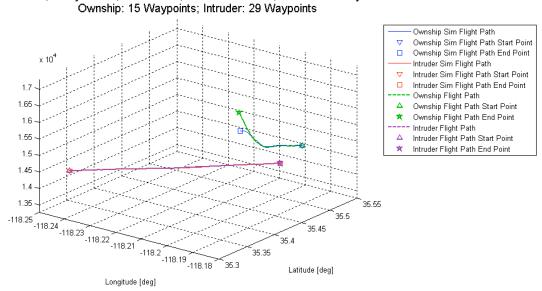


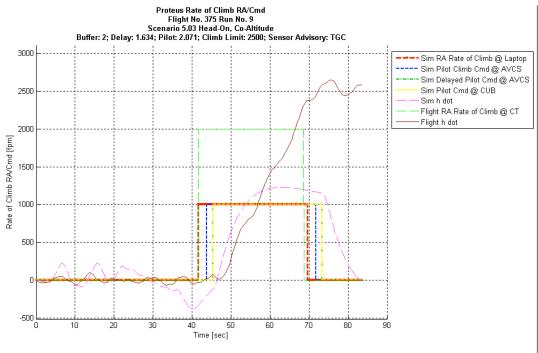
Generic G-III Time History Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

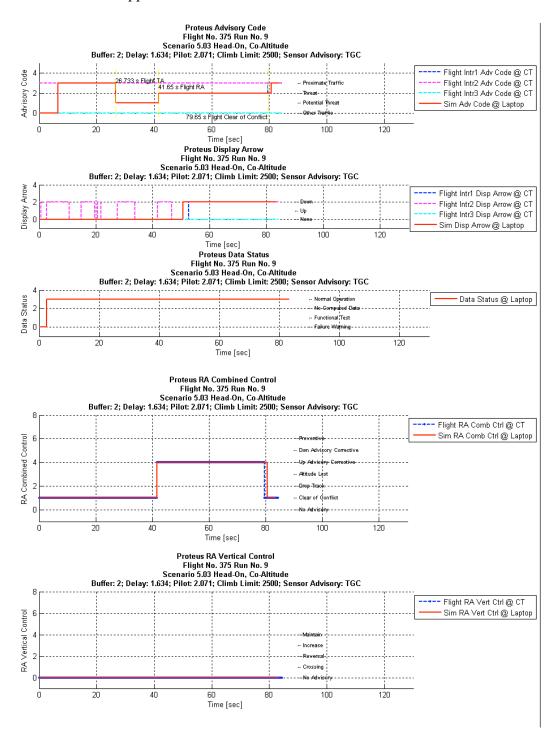


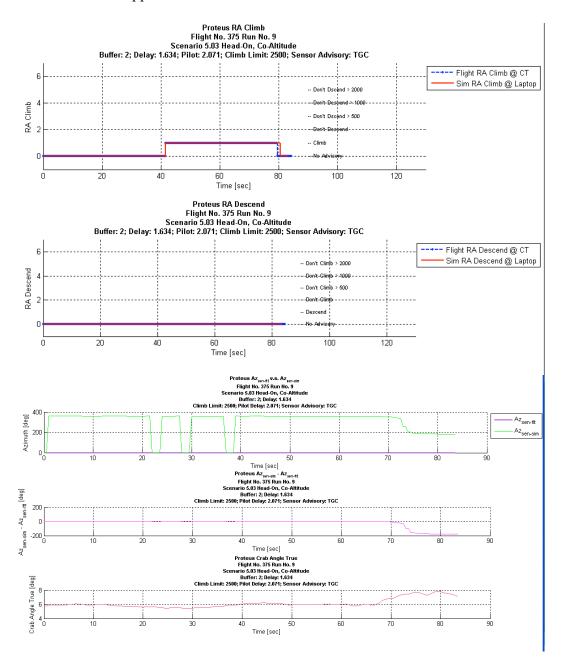
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 9 Scenario 5.03 Head-On, Co-Altitude

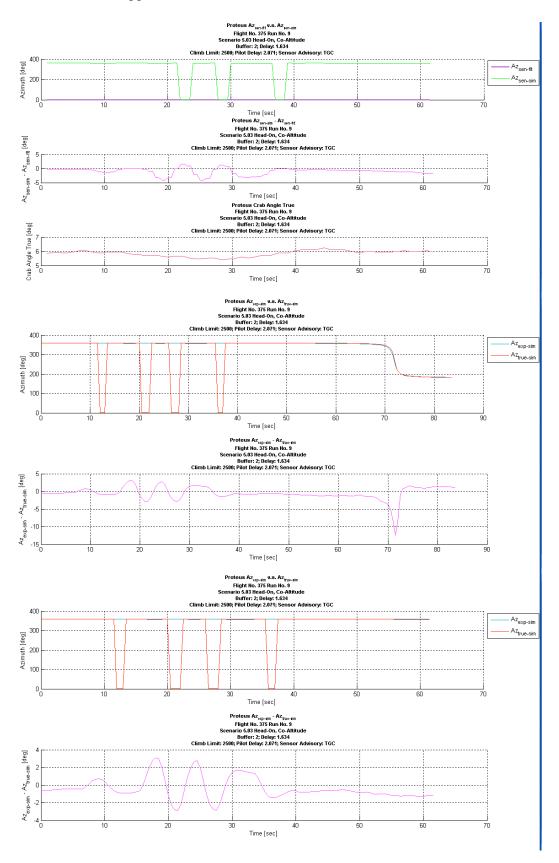
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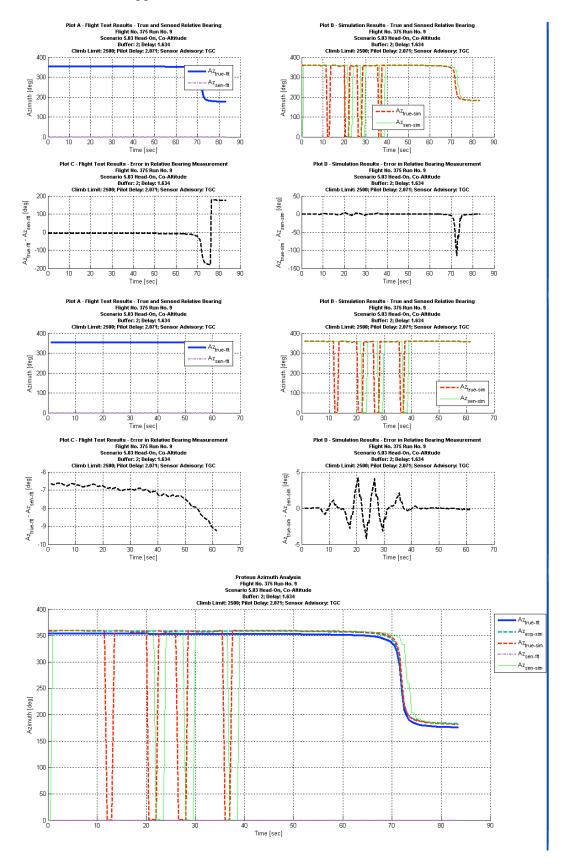


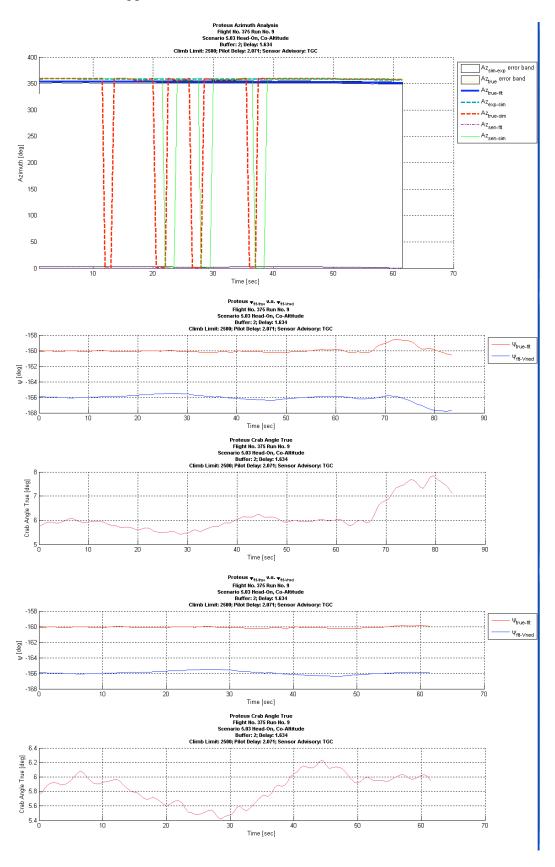


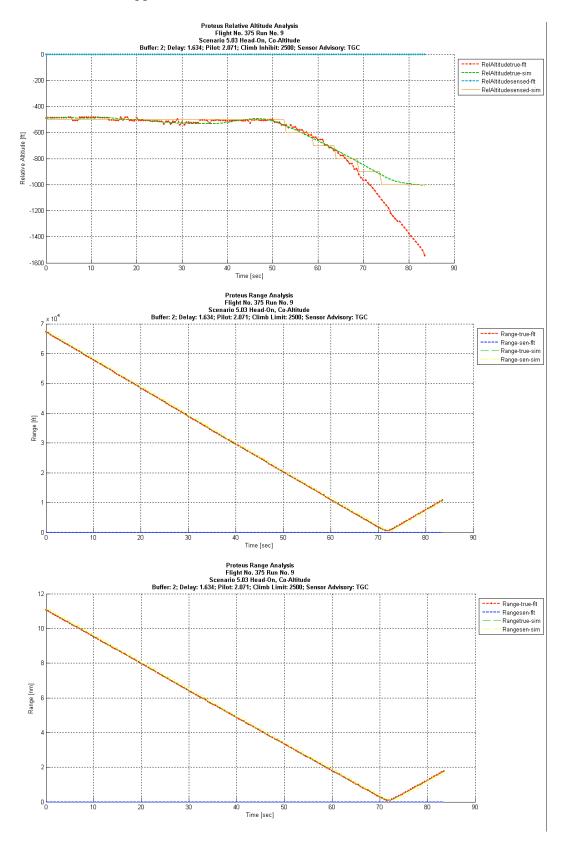








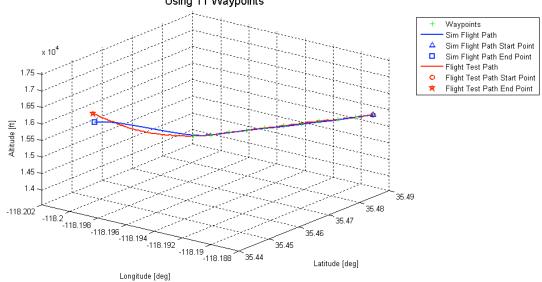




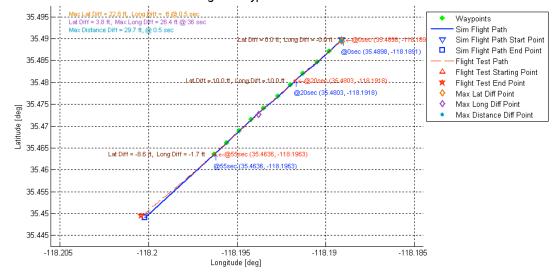
Flight 375 Run 11

Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

Proteus 3-D Plot

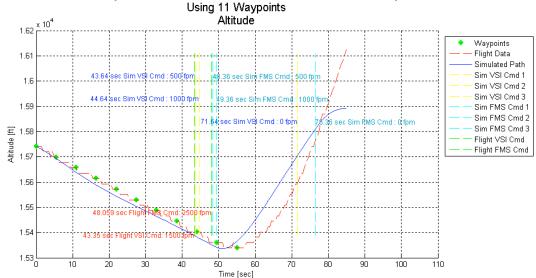


Proteus Flight Path Position Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending



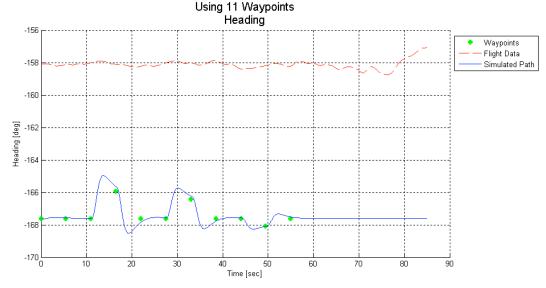
Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC



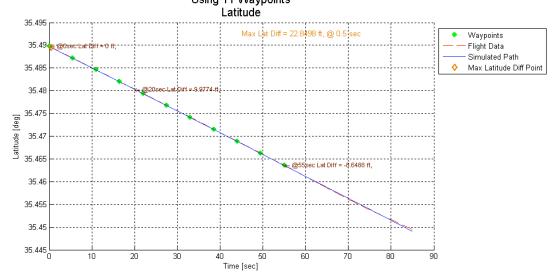
Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC

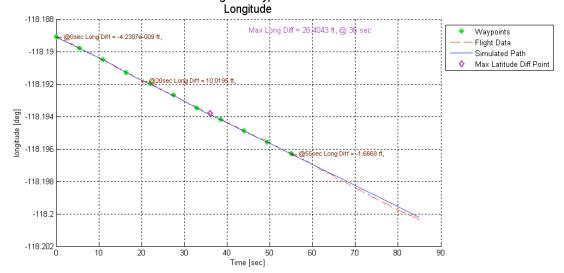


Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints



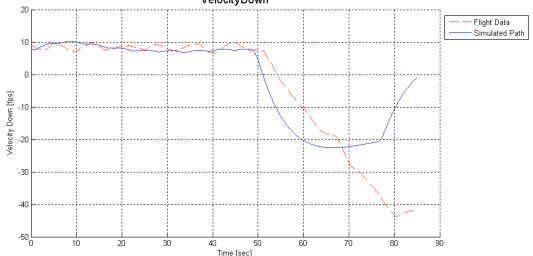
Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending



Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC

Using 11 Waypoints VelocityDown



Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC

Using 11 Waypoints VelocityEast

Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

VelocityNorth

-150

-160

-166

-170

-170

-180

-180

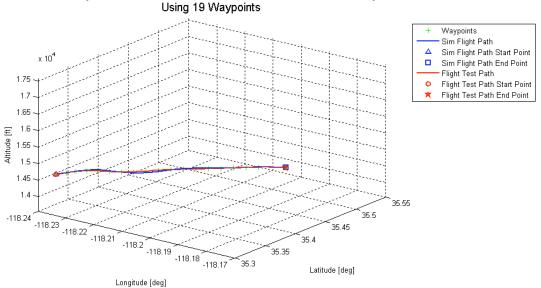
-180

10 20 30 40 50 60 70 80 90

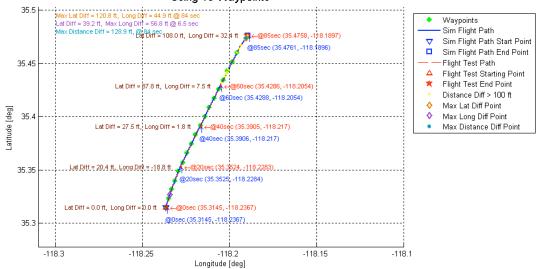
Proteus Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

Generic G-III 3-D Plot
Flight No. 375 Run No. 11
Scenario 6.03 Head-On, Host Descending
Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Inhibit: 2500; Sensor Advisory: TGC

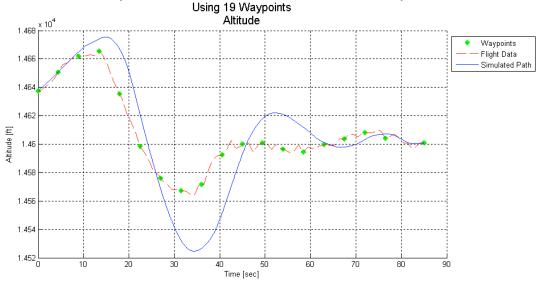


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending



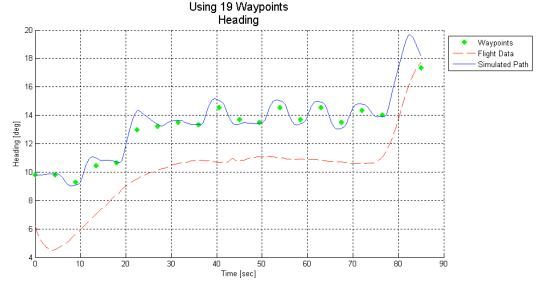
Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC



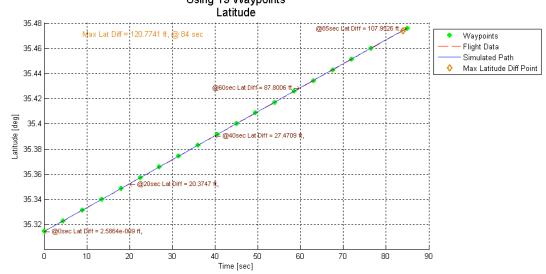
Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC

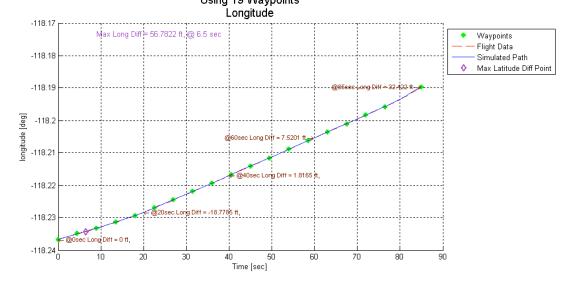


Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



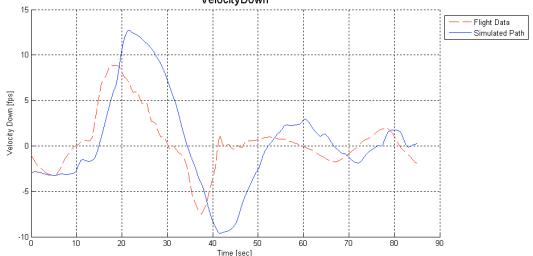
Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending



Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC

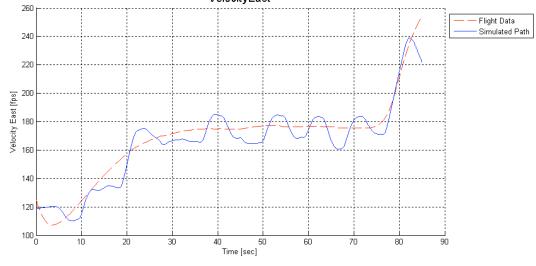
Using 19 Waypoints VelocityDown



Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC

Using 19 Waypoints VelocityEast



Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints

VelocityNorth

710

705

695

690

670

670

666

10 20 30 40 50 60 70 80 90

Generic G-III Time History Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

Buffer: 2; Delay: 1.634; Pilot: 3.075; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints

VelocityTrue

* Waypoints — Flight Data — Simulated Path

435

425

410

10

20

30

40

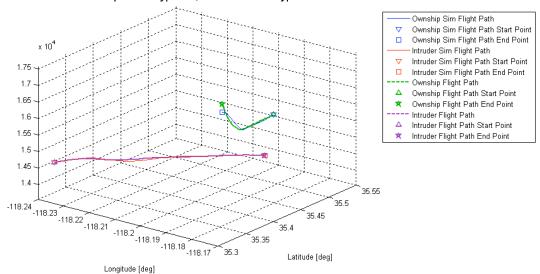
50

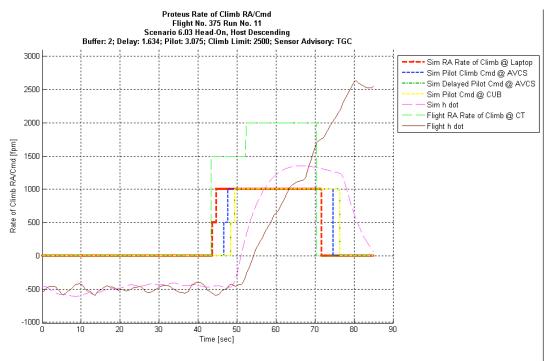
Time [sec]

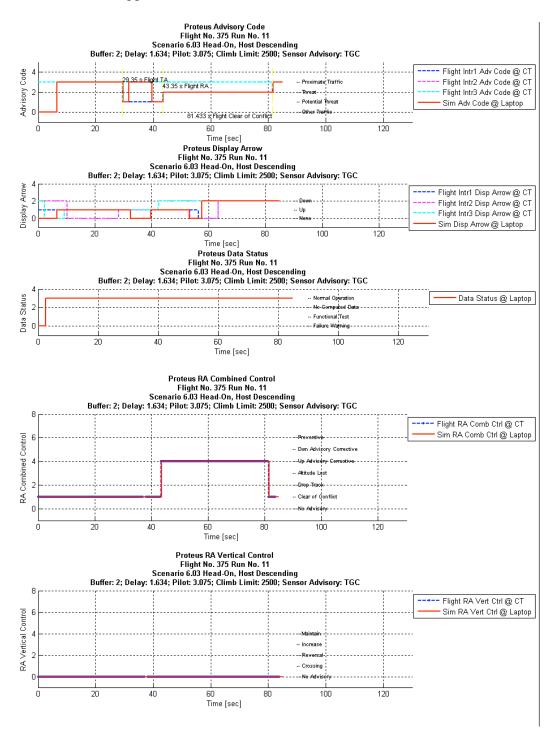
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 11 Scenario 6.03 Head-On, Host Descending

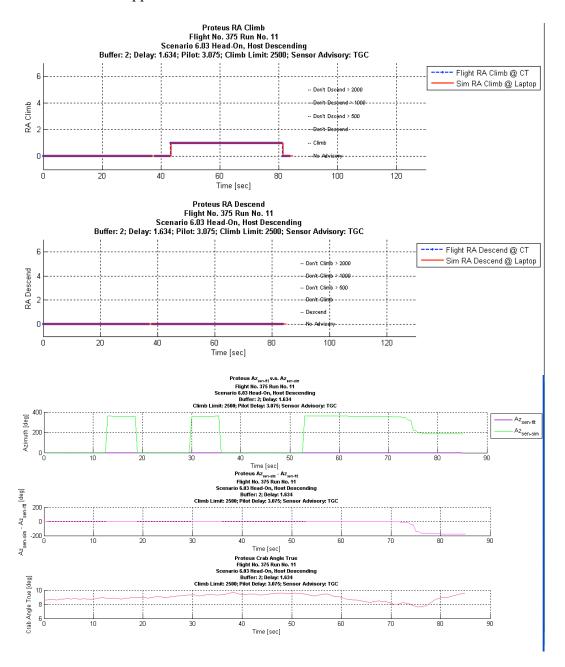
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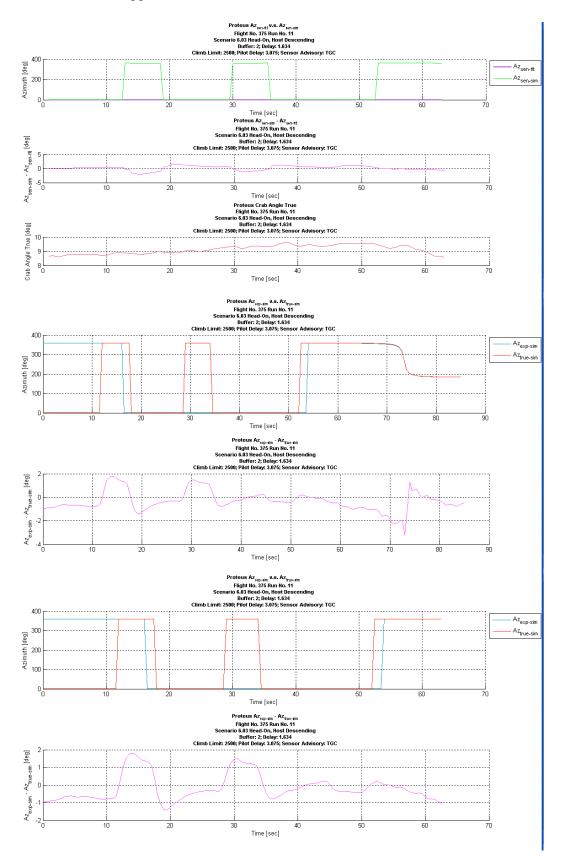
Ownship: 11 Waypoints; Intruder: 19 Waypoints

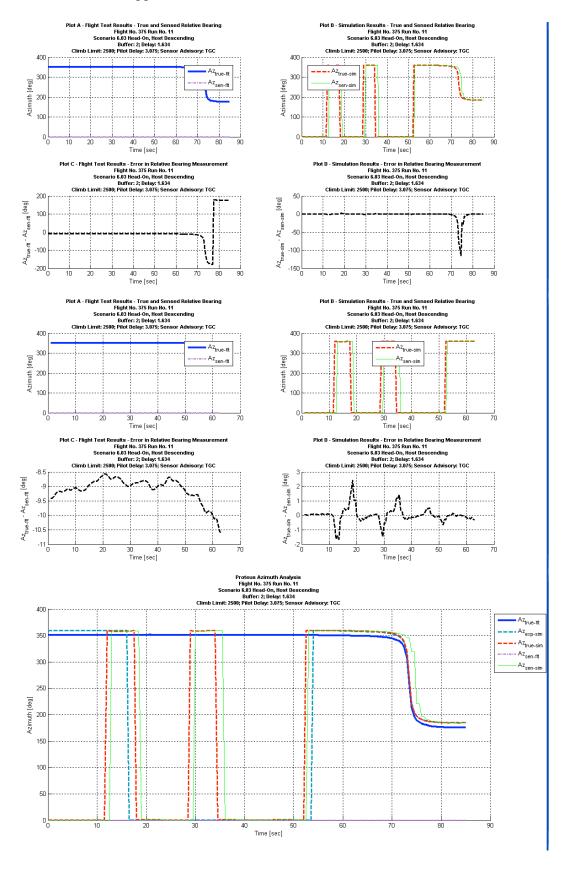


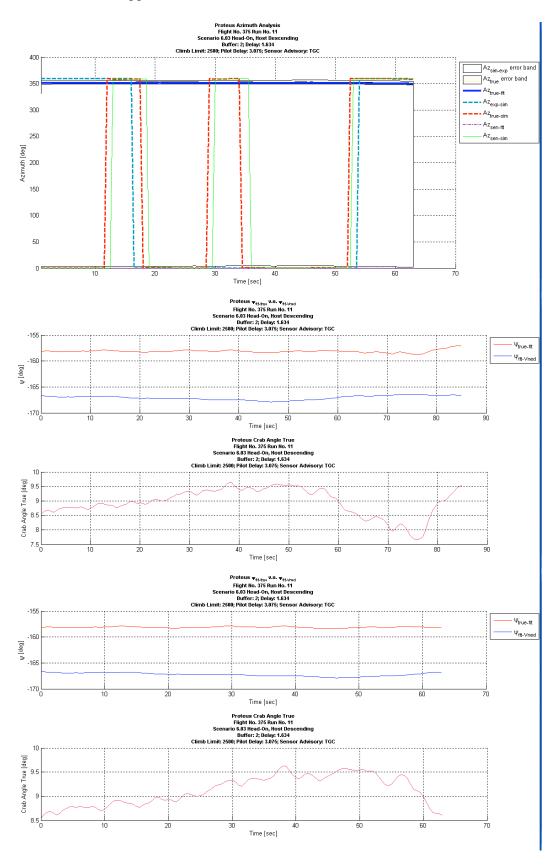


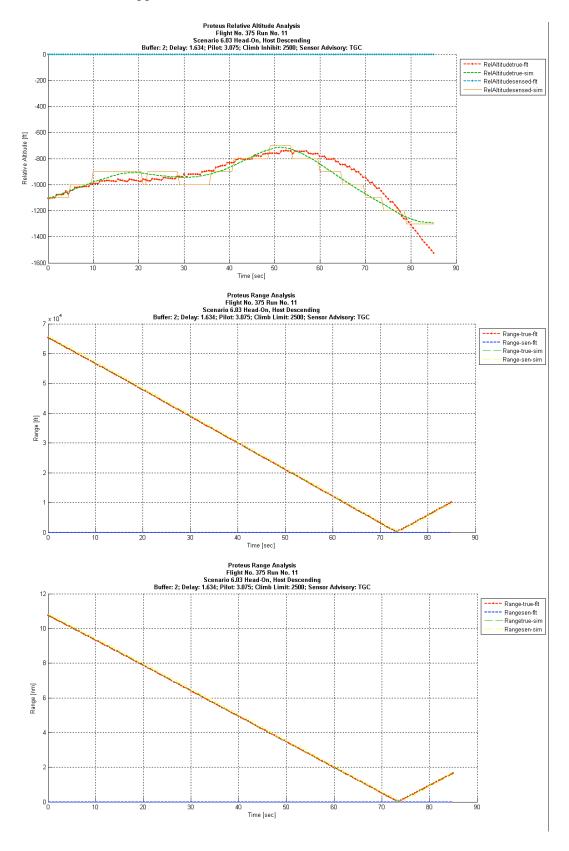








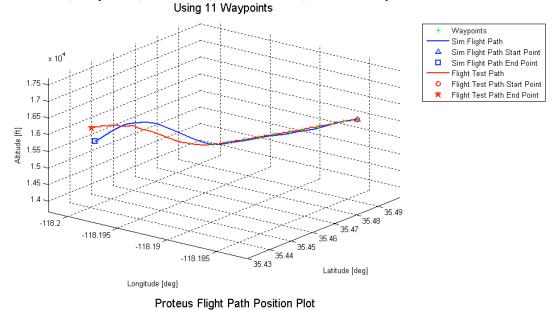




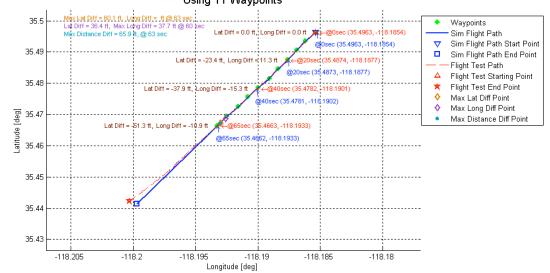
Flight 375 Run 12

Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Limit: 2500; Sensor Advisory: TGC

Proteus 3-D Plot

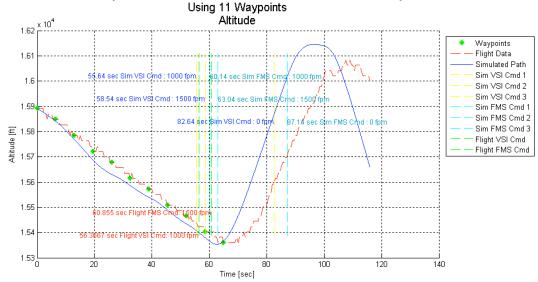


Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

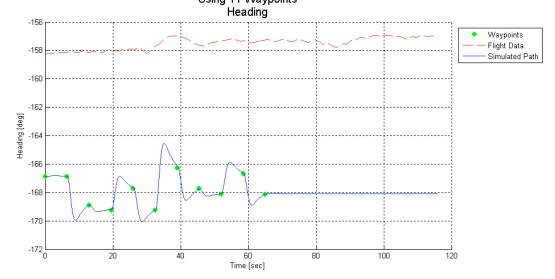


Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending



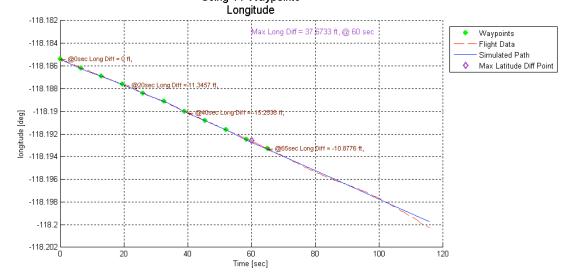
Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

> Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

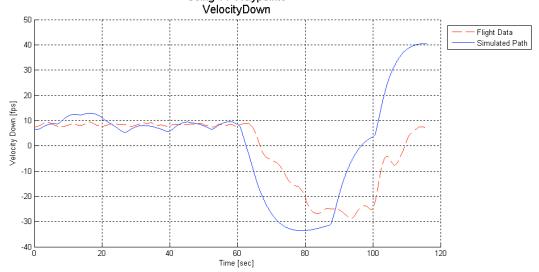
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Time [sec]

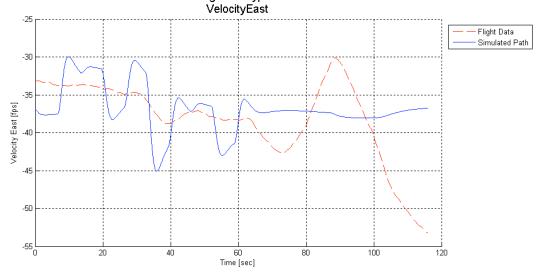


Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

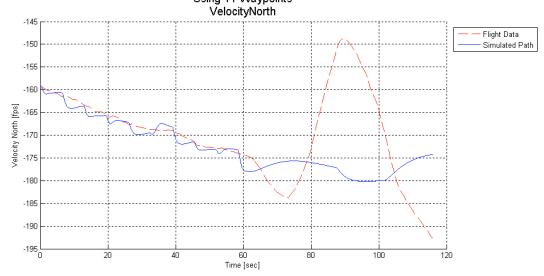


Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

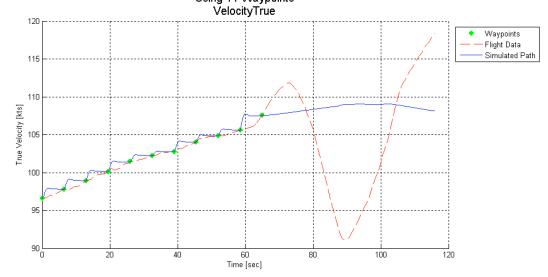


Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

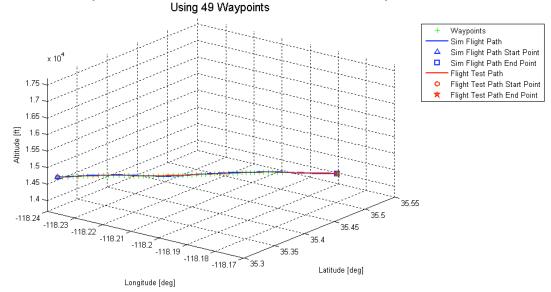


Proteus Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

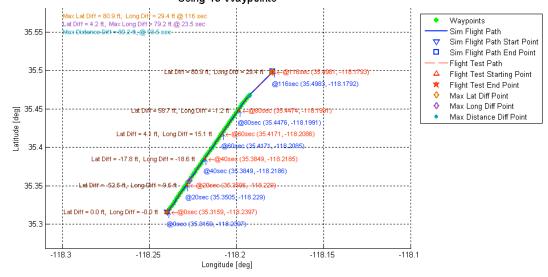


Generic G-III 3-D Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 2.8543; Climb Inhibit: 2500; Sensor Advisory: TGC

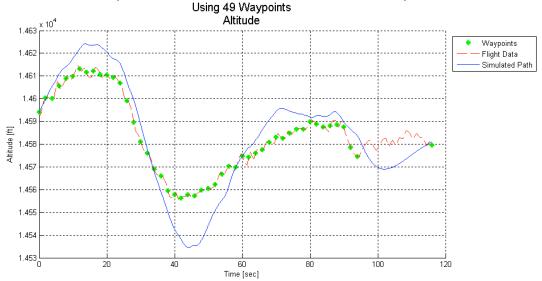


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

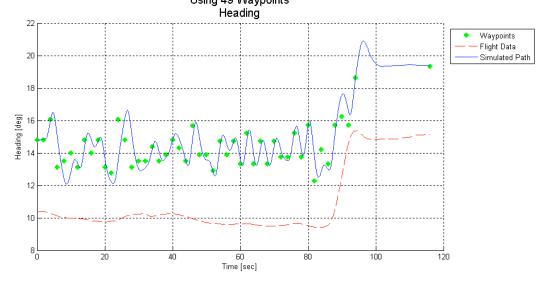


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

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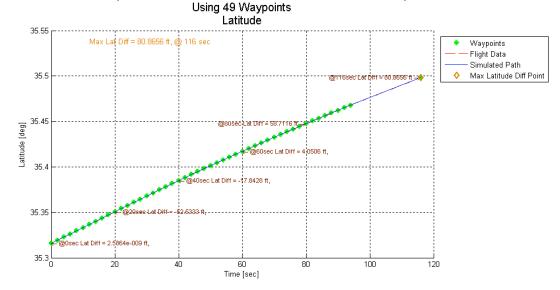


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

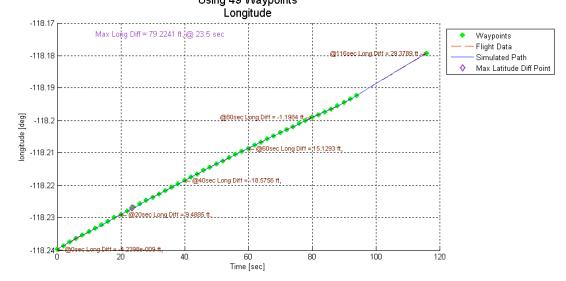


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

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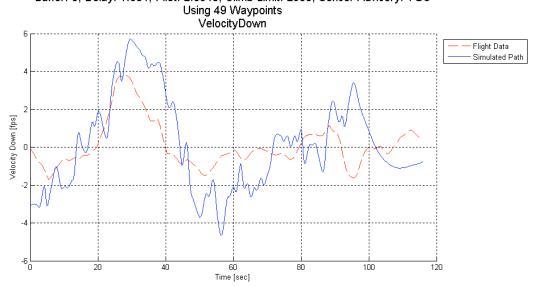


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

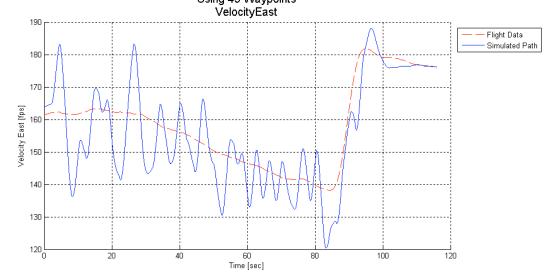


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

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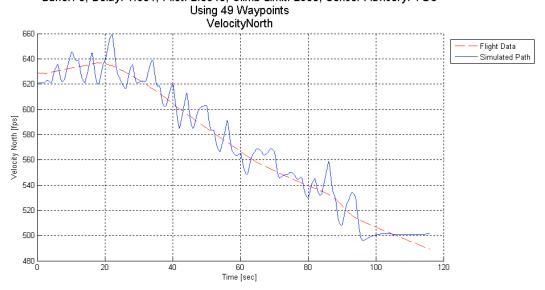


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

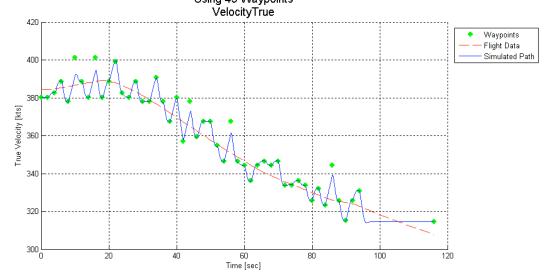


Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

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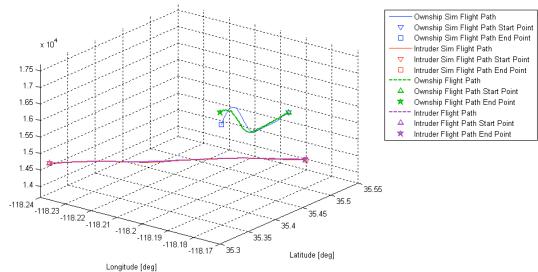
Generic G-III Time History Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

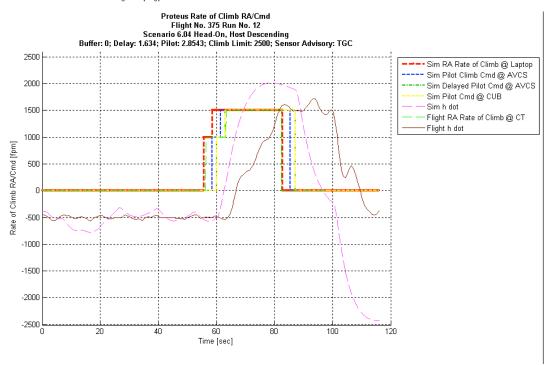


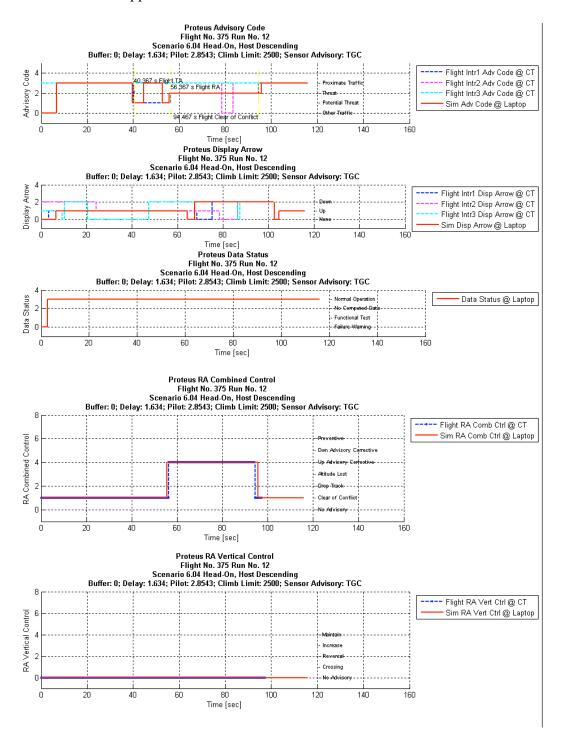
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 12 Scenario 6.04 Head-On, Host Descending

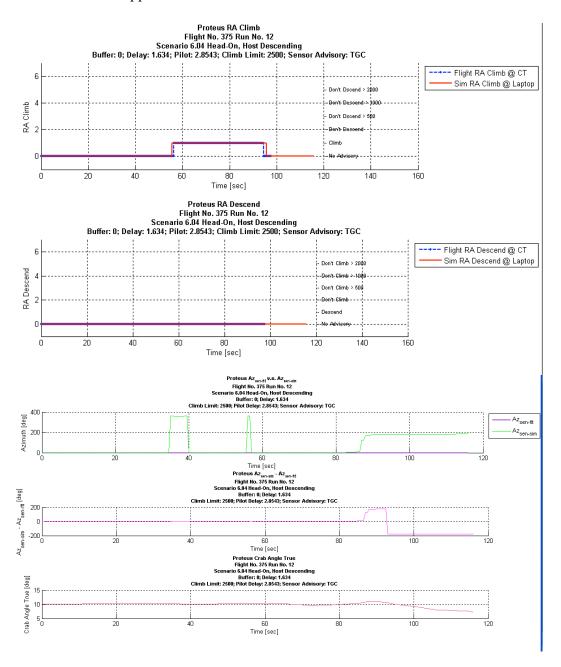
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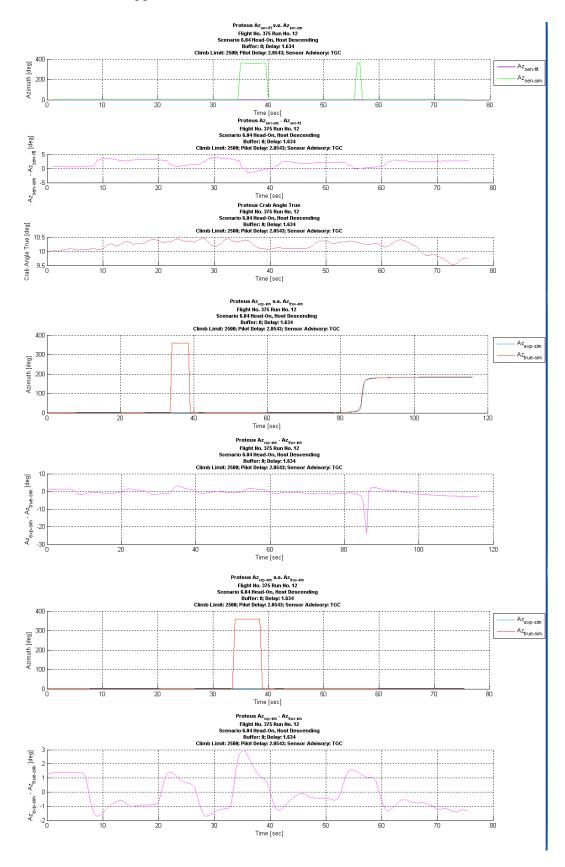


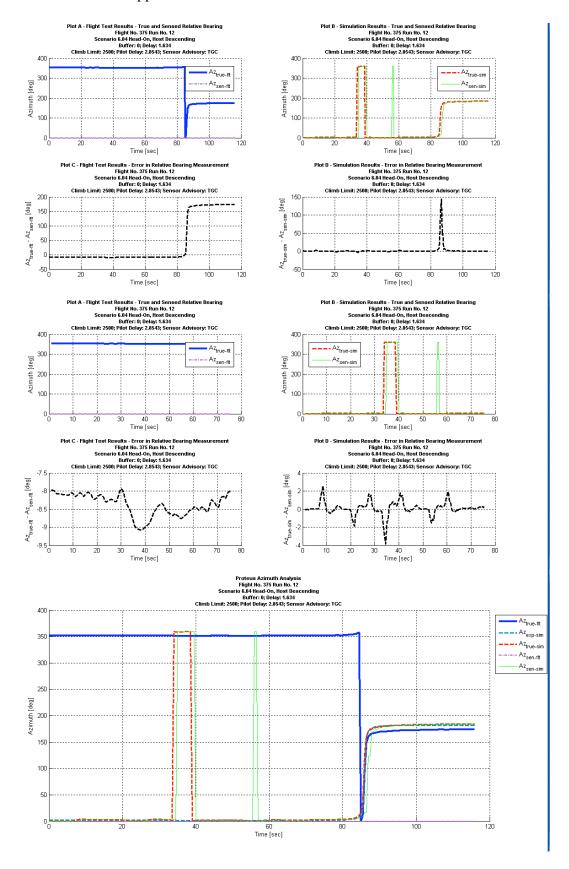


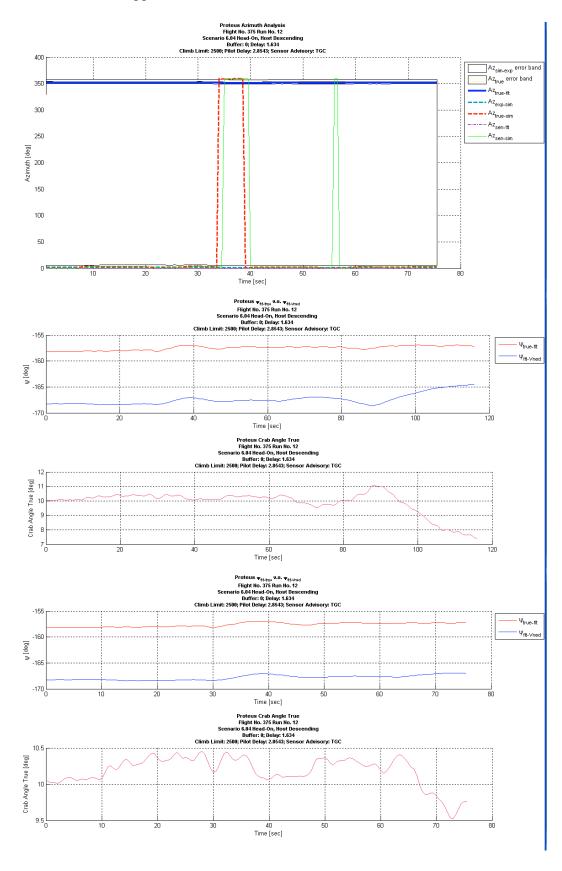


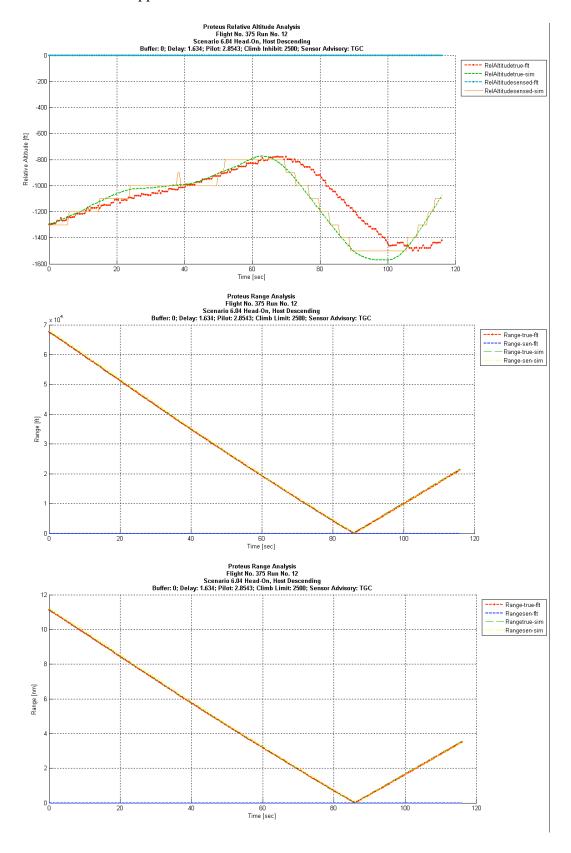








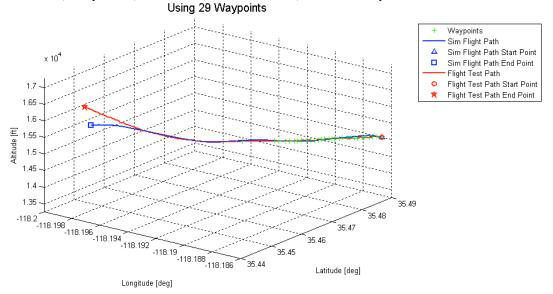




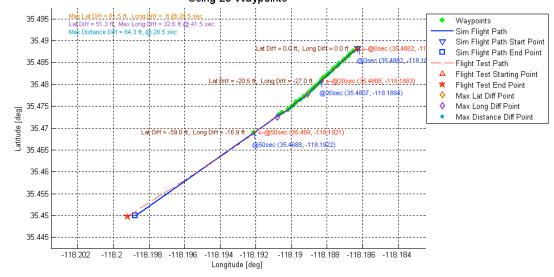
Flight 375 Run 13

Proteus 3-D Plot
Flight No. 375 Run No. 13
Scenario 4.01 Abeam, Co-Altitude
uffer: 6: Delay: 1.634: Pilot: 4.7503: Climb Limit: 2500: Se

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC

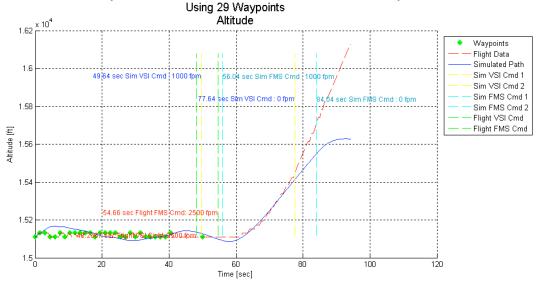


Proteus Flight Path Position Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

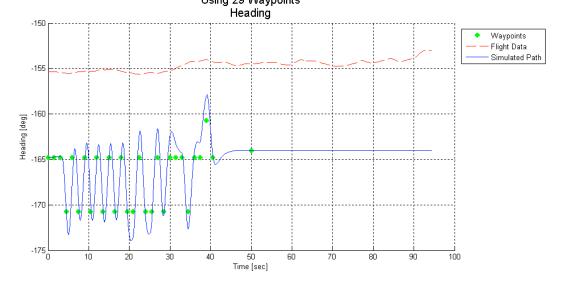


Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

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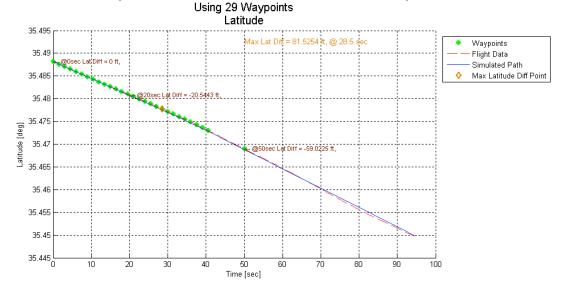


Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

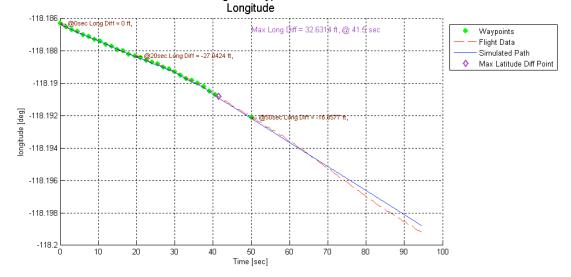


Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

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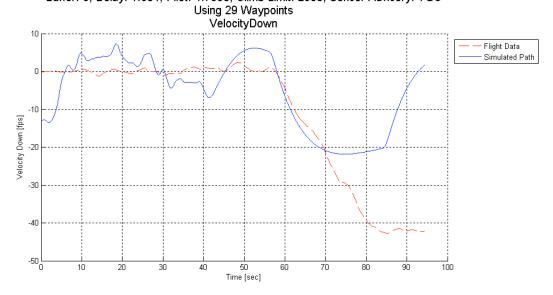


Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

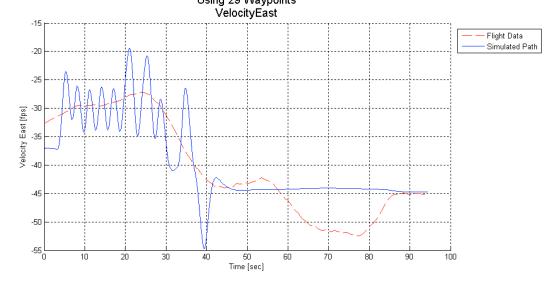


Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

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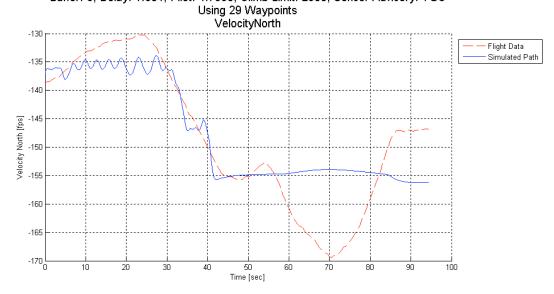


Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude



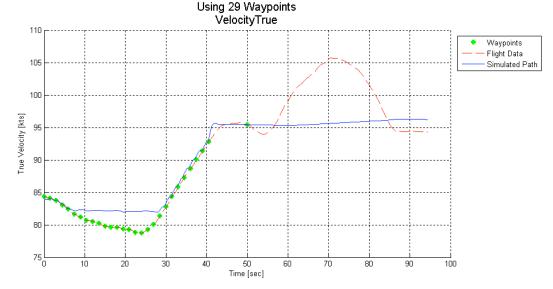
Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC



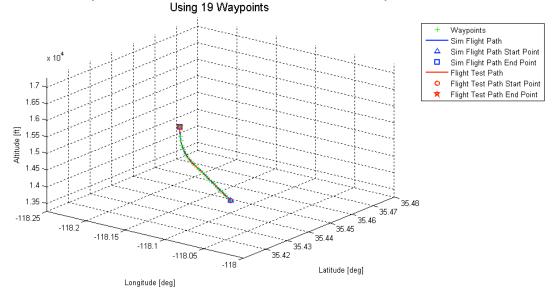
Proteus Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC

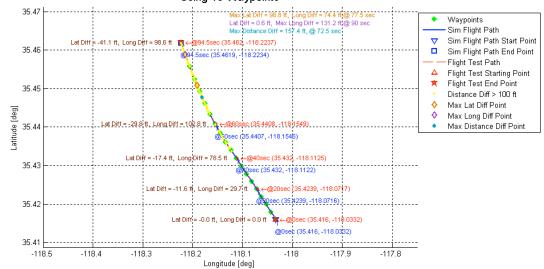


Generic G-III 3-D Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Inhibit: 2500; Sensor Advisory: TGC

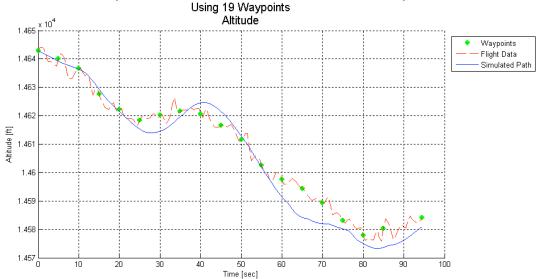


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

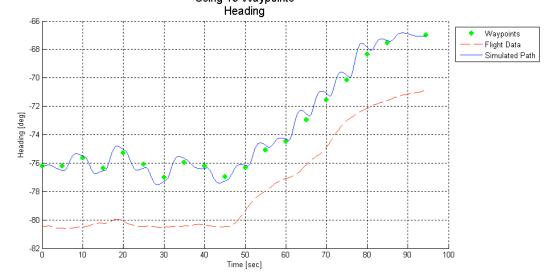


Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC

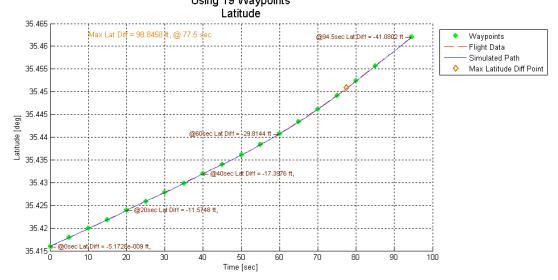


Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

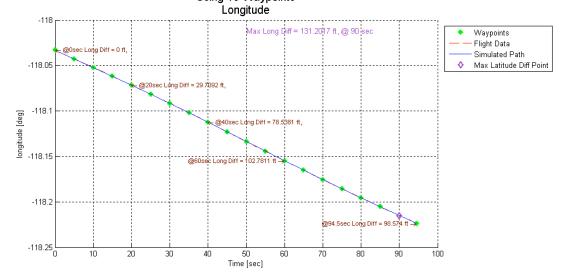


Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

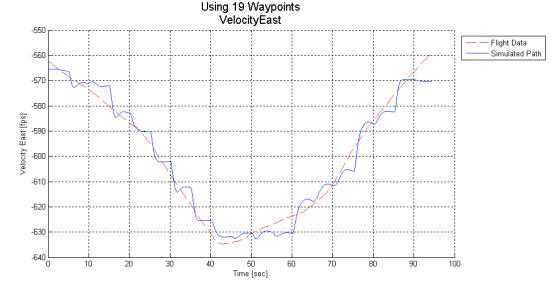


Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints VelocityDown

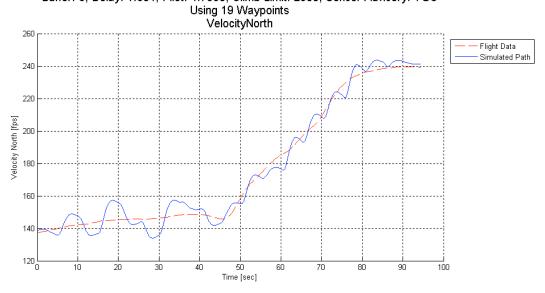
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Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC

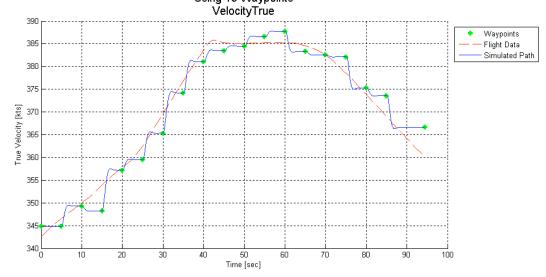


Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

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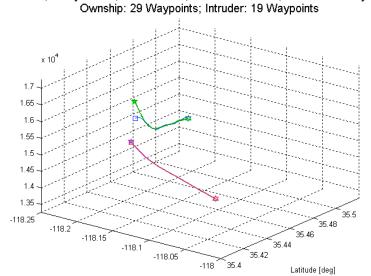


Generic G-III Time History Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude



Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 13 Scenario 4.01 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.7593; Climb Limit: 2500; Sensor Advisory: TGC



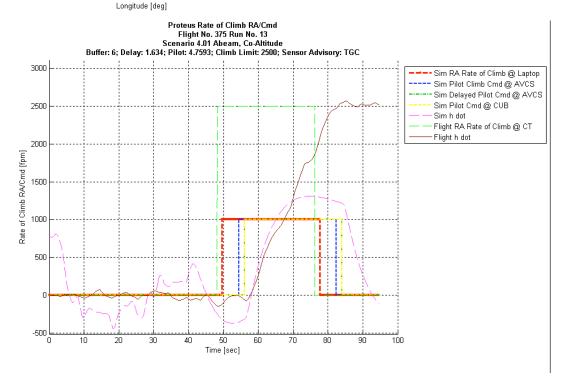
Ownship Sim Flight Path Start Point
 Ownship Sim Flight Path End Point
 Intruder Sim Flight Path

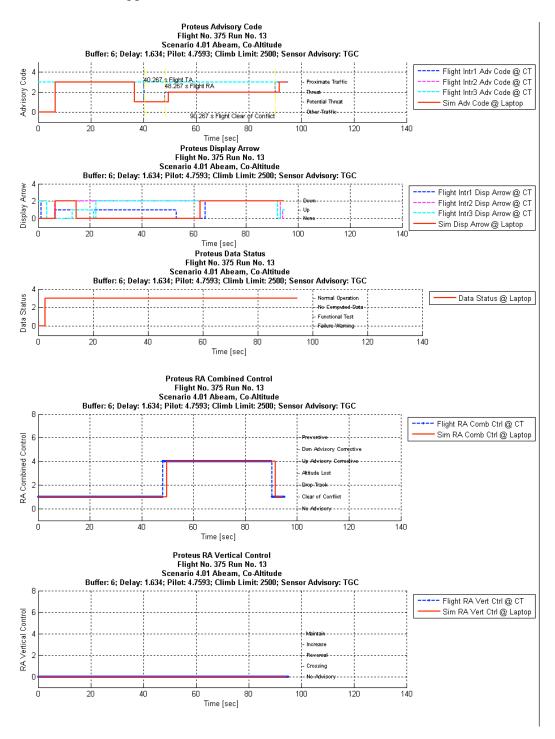
✓ Intruder Sim Flight Path Start Point☐ Intruder Sim Flight Path End Point

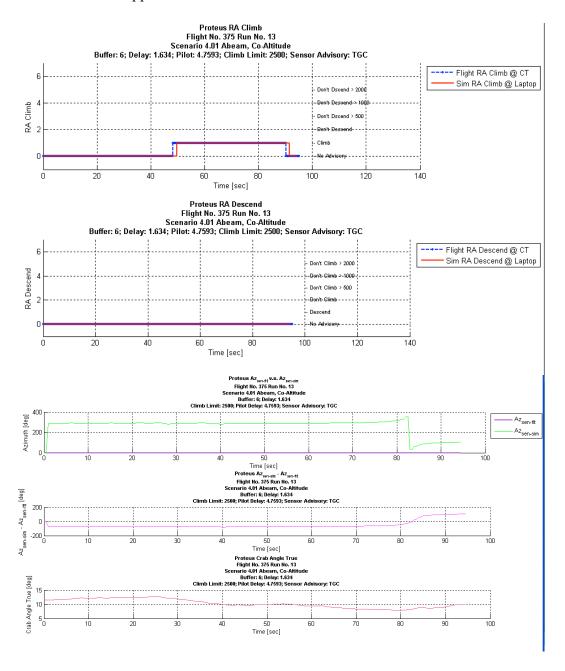
Ownship Sim Flight Path

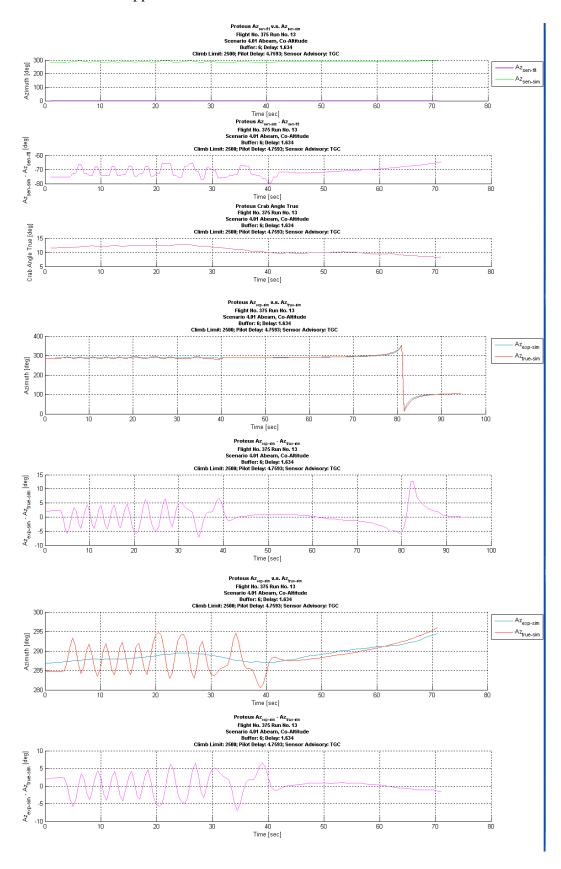
- ---- Ownship Flight Path

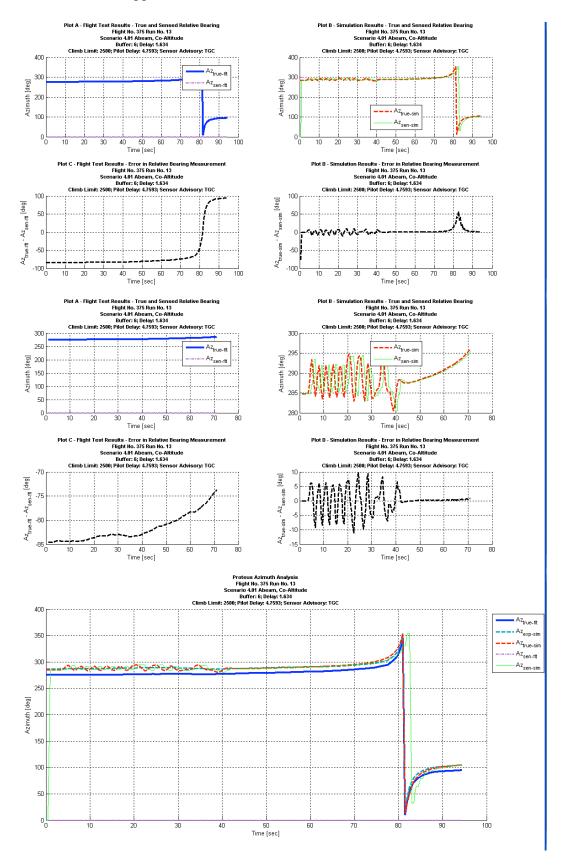
 Ownship Flight Path Start Point
- ★ Ownship Flight Path End Point ----- Intruder Flight Path
- △ Intruder Flight Path Start Point
- ★ Intruder Flight Path End Point

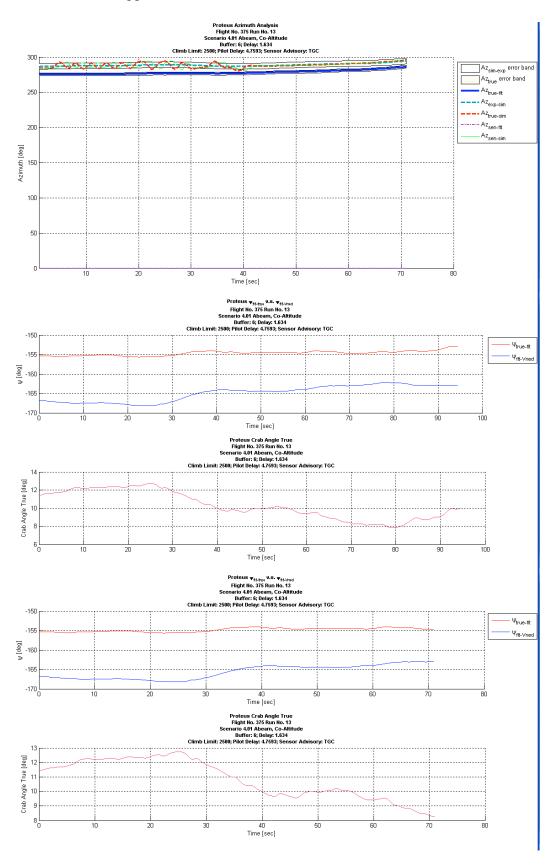


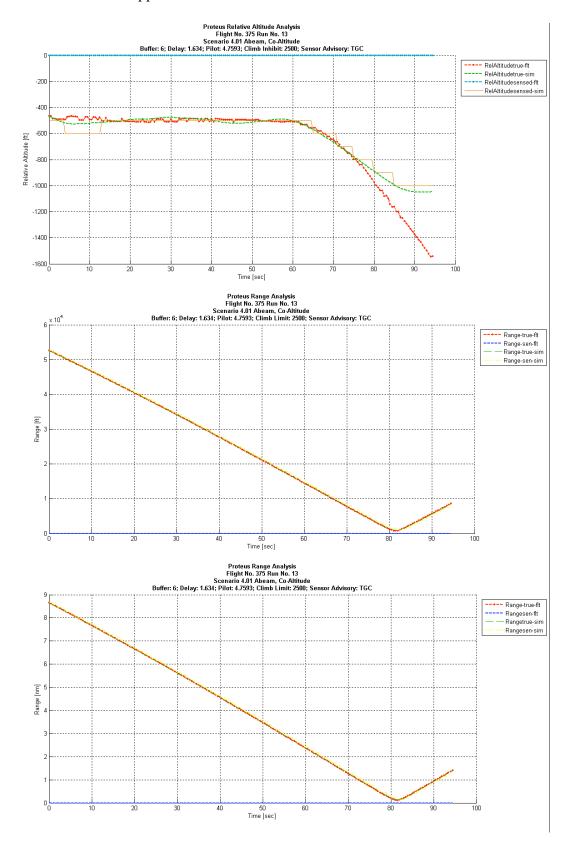






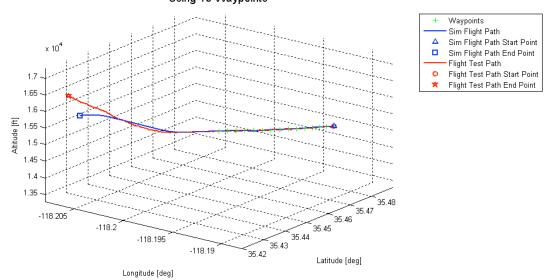




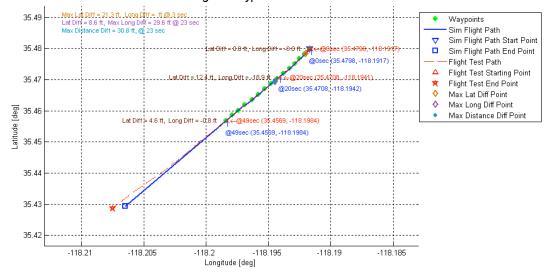


Flight 375 Run 15

Proteus 3-D Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints

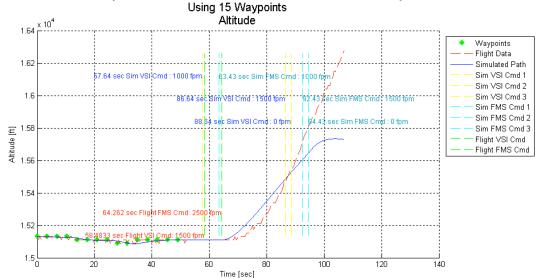


Proteus Flight Path Position Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude



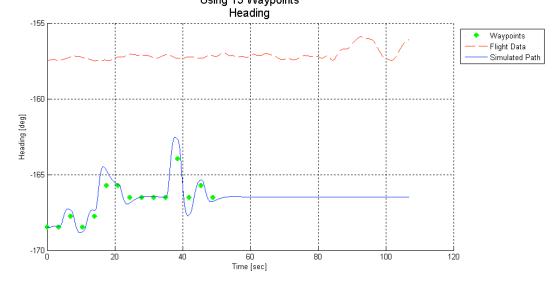
Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC



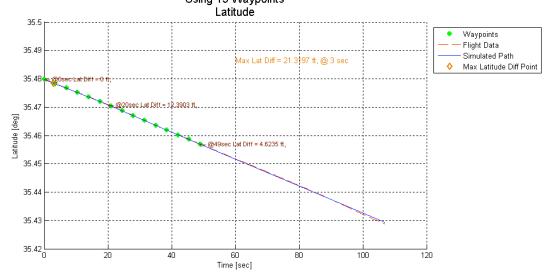
Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints

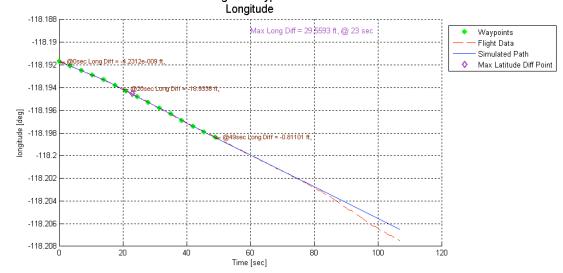


Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC Using 15 Waypoints

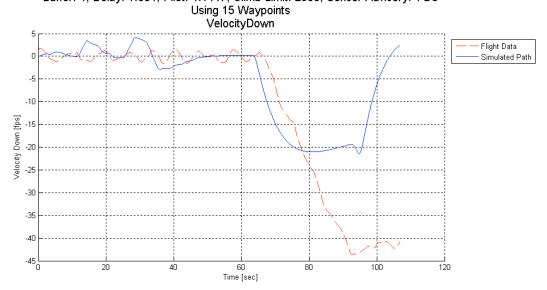


Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

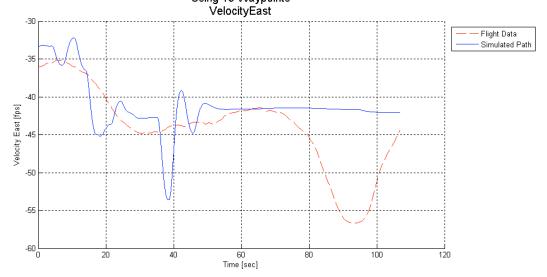


Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC

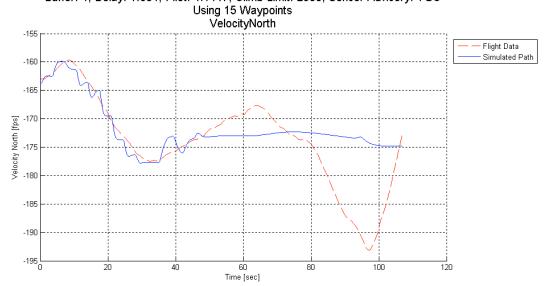


Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

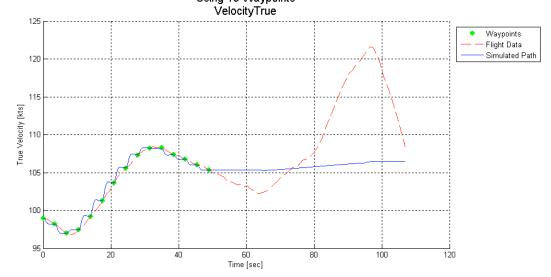


Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

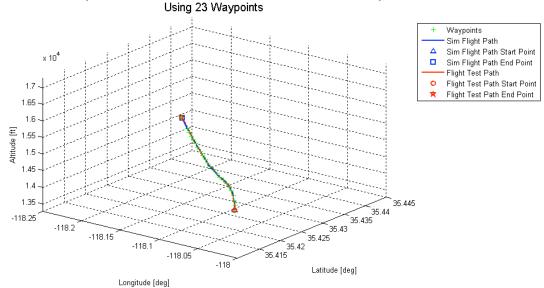
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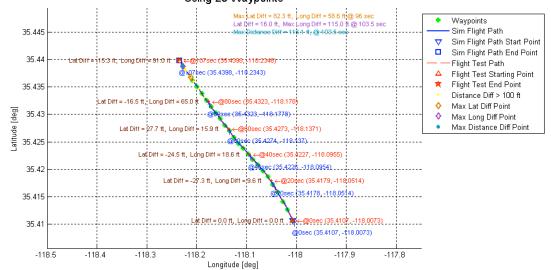
Proteus Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude



Generic G-III 3-D Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Inhibit: 2500; Sensor Advisory: TGC

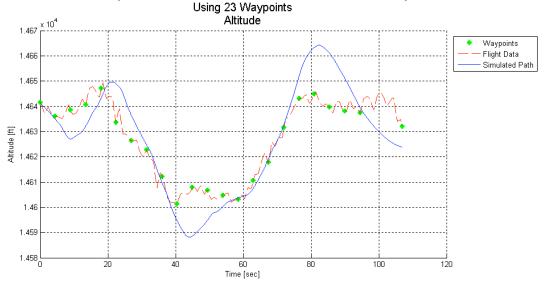


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

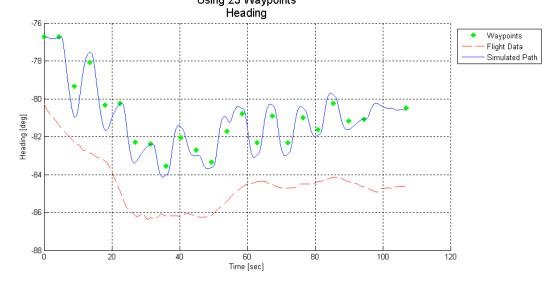


Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC

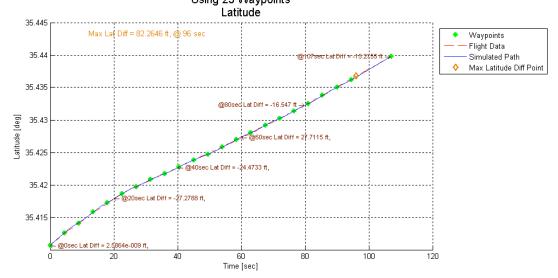


Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude



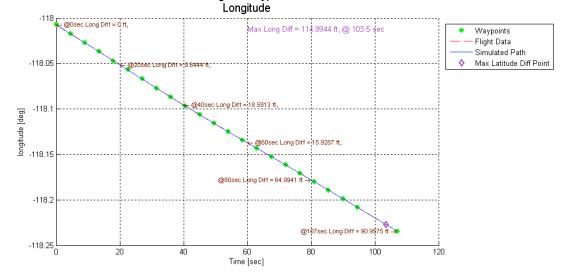
Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC Using 23 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC Using 23 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

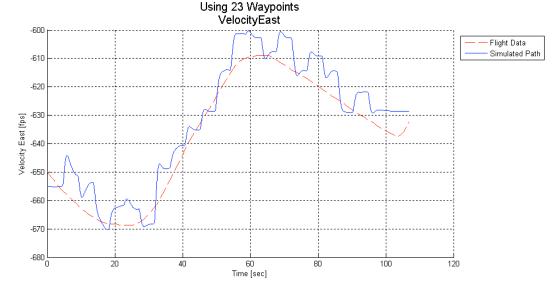
Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC

Using 23 Waypoints
VelocityDown

Flight Data
Simulated Path

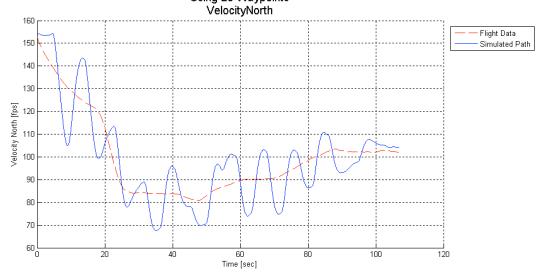
Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

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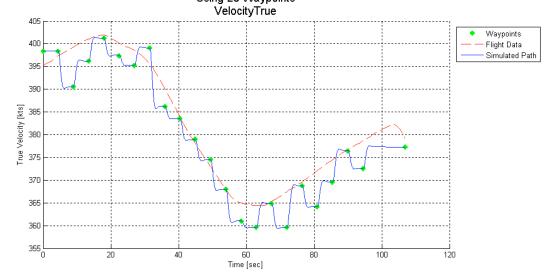


Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 4.1447; Climb Limit: 2500; Sensor Advisory: TGC Using 23 Waypoints

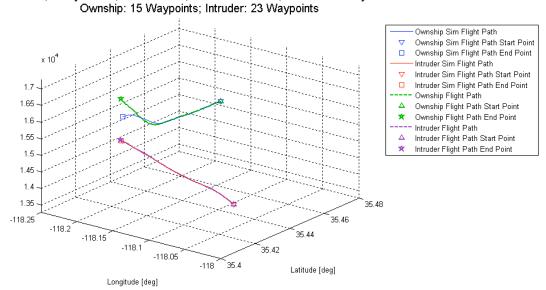


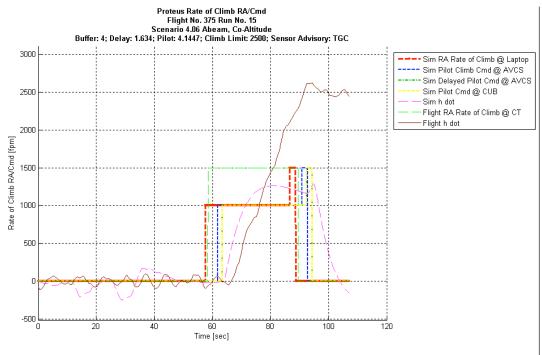
Generic G-III Time History Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

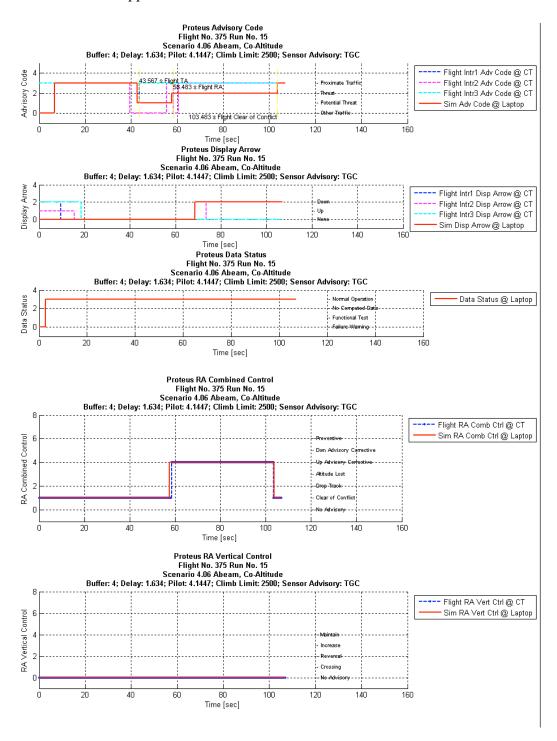


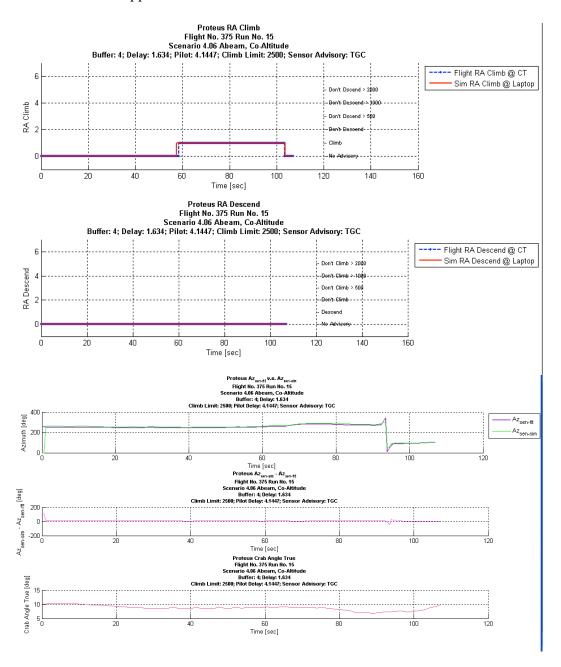
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 15 Scenario 4.06 Abeam, Co-Altitude

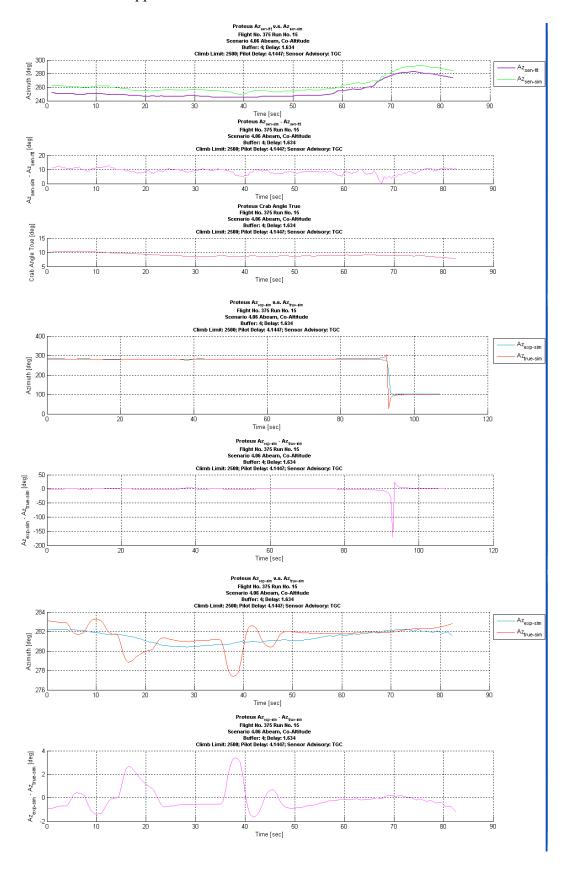
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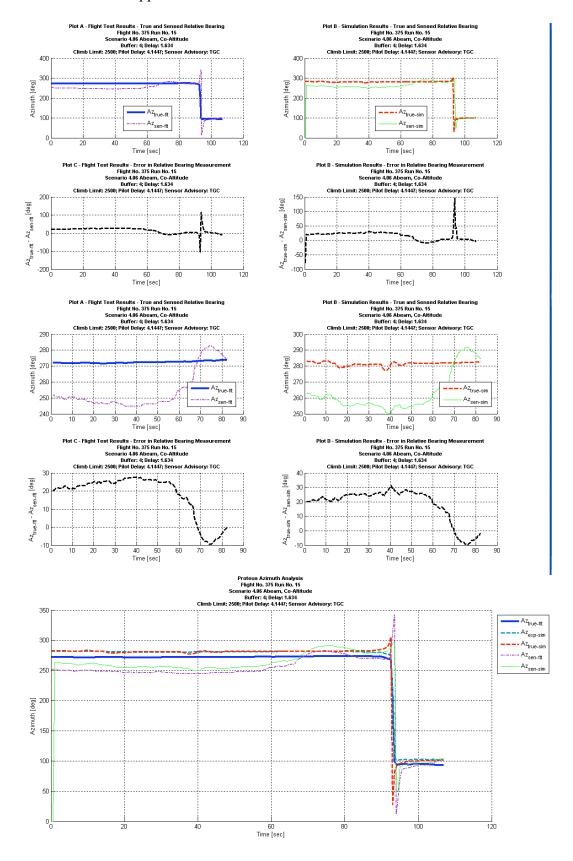


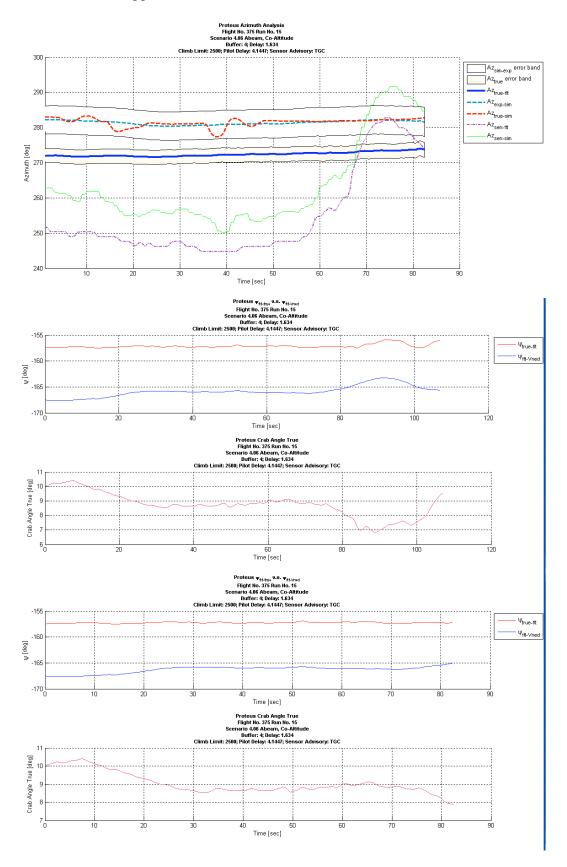


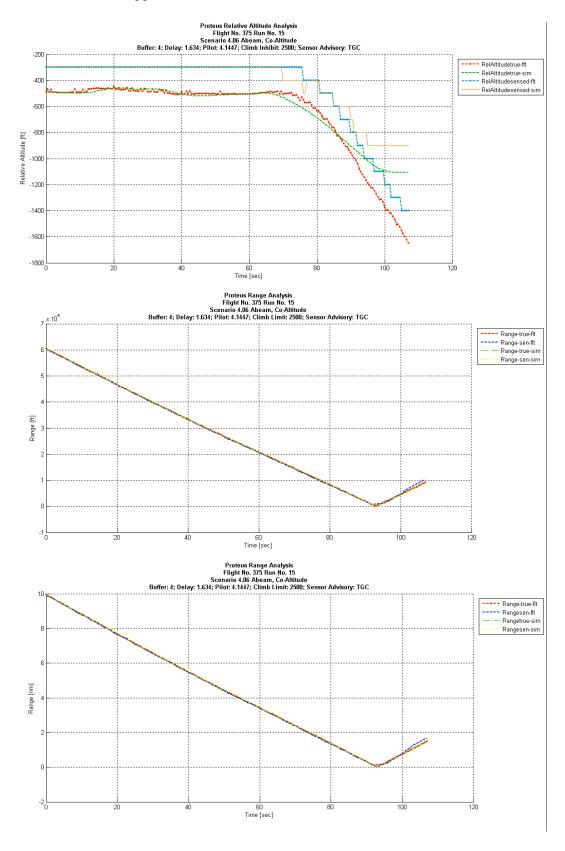








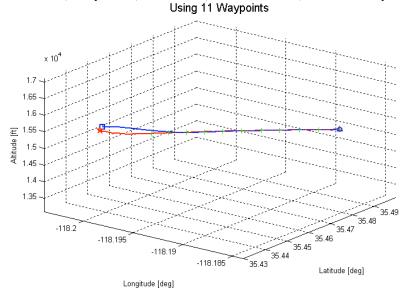




Flight 375 Run 17

Proteus 3-D Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

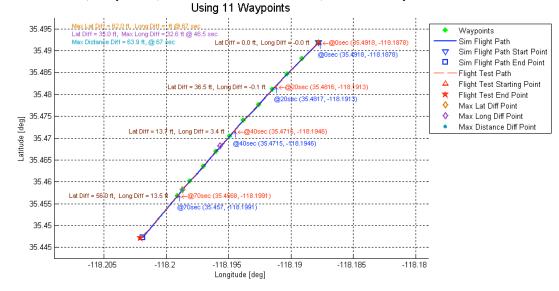
Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC



+ Waypoints
Sim Flight Path
△ Sim Flight Path Start Point
□ Sim Flight Path End Point
− Flight Test Path
○ Flight Test Path Start Point
★ Flight Test Path End Point

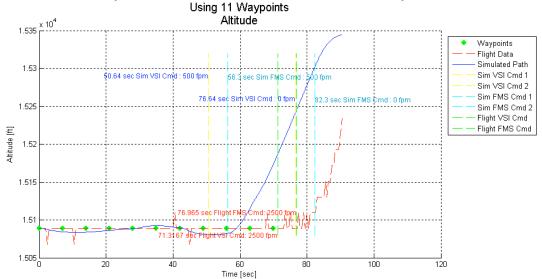
Proteus Flight Path Position Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC

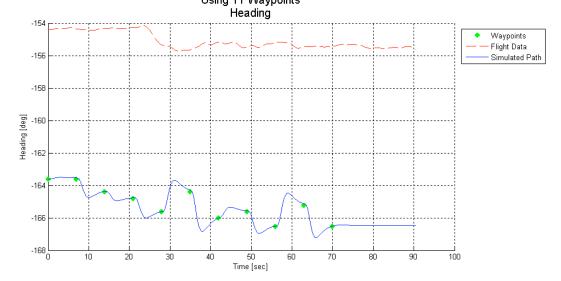


Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC

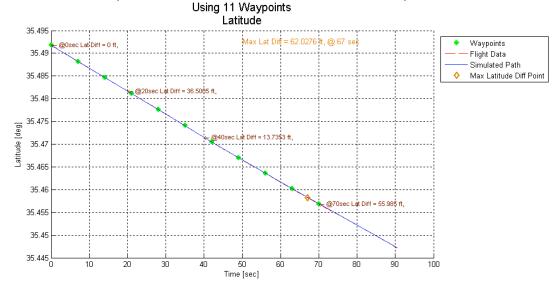


Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

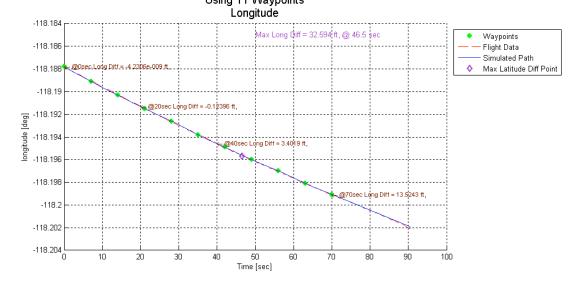


Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC



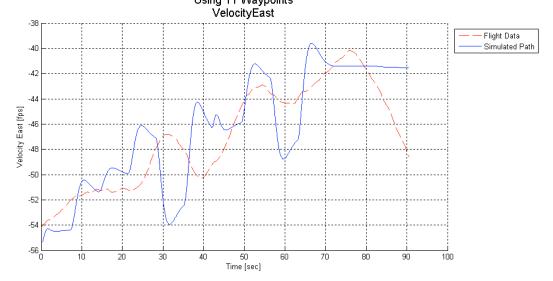
Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude



Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

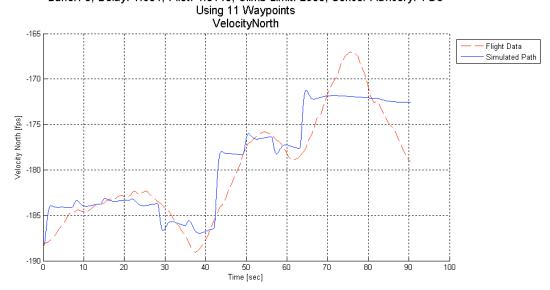
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> Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

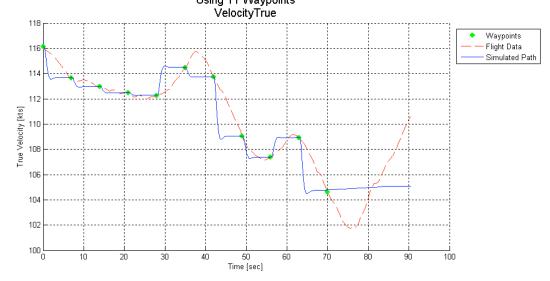


Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC

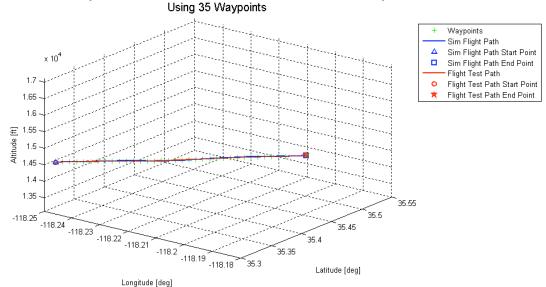


Proteus Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude



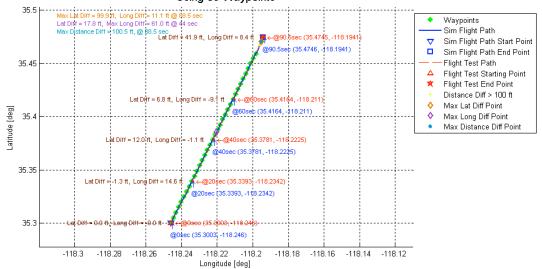
Generic G-III 3-D Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Inhibit: 2500; Sensor Advisory: TGC



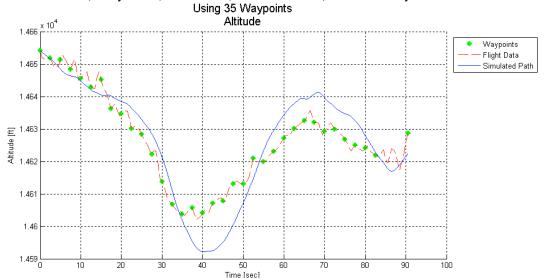
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC Using 35 Waypoints

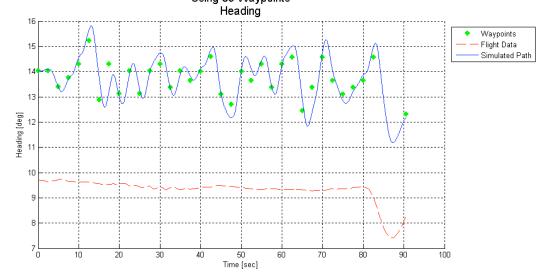


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC

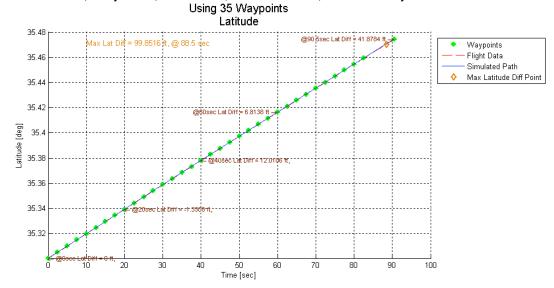


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

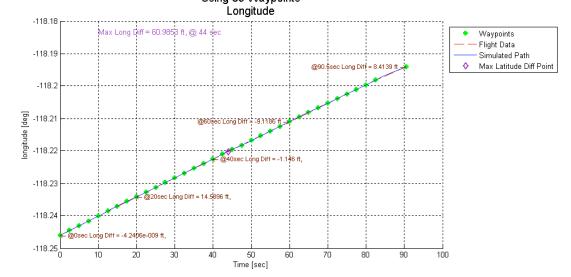


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

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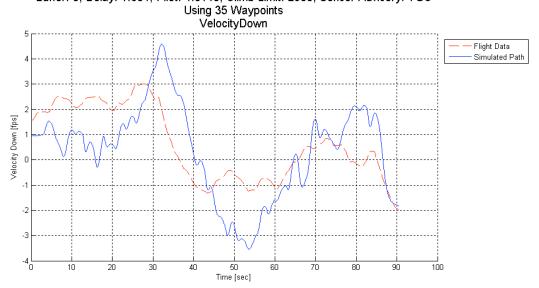


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

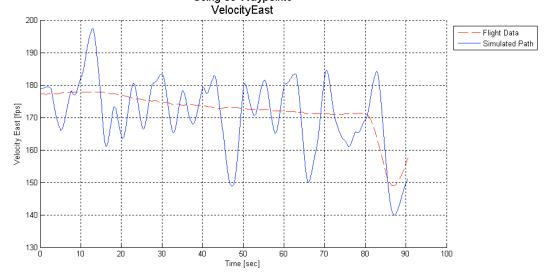


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC

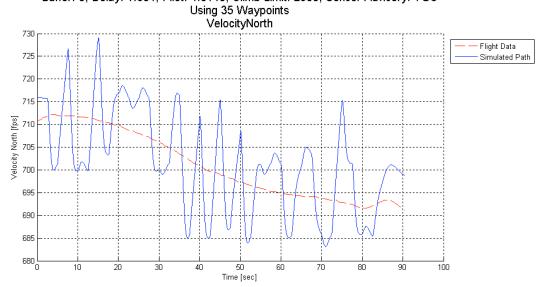


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

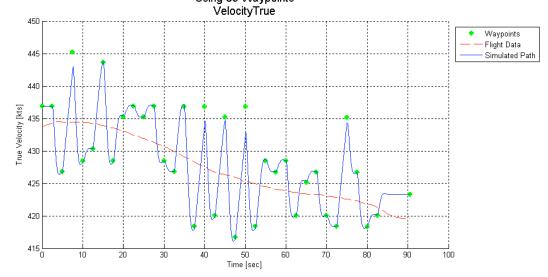


Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.0143; Climb Limit: 2500; Sensor Advisory: TGC

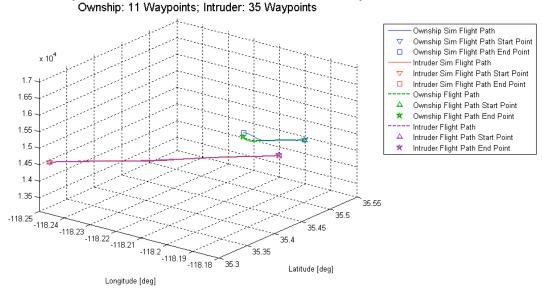


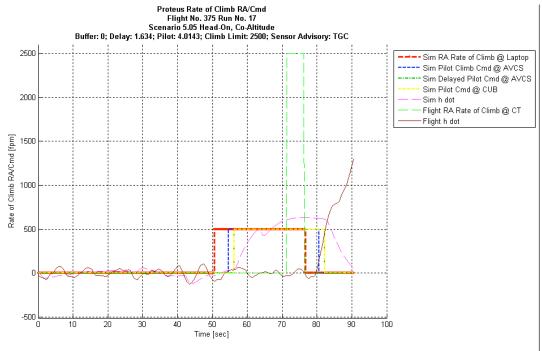
Generic G-III Time History Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

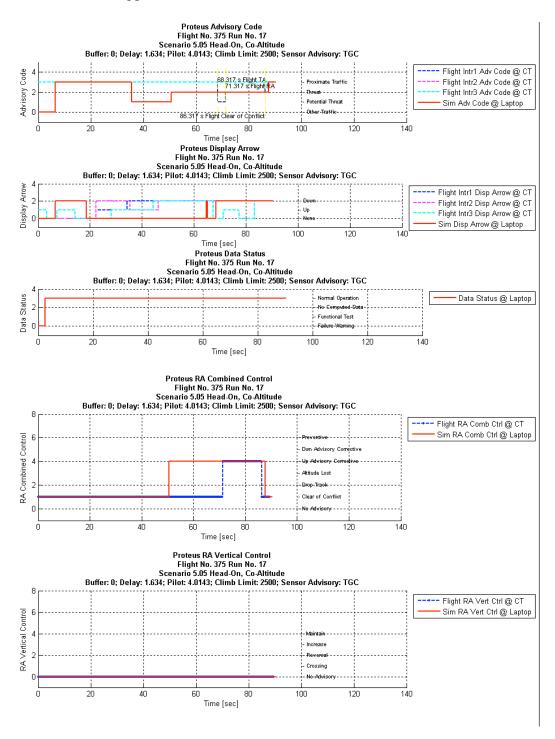


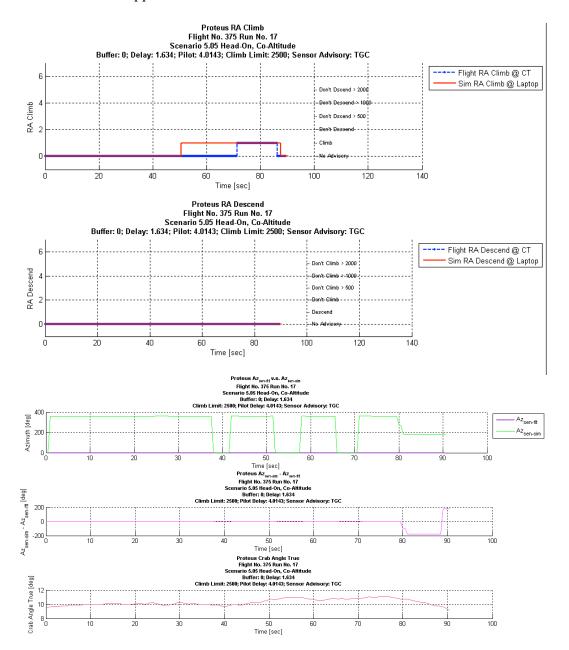
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 17 Scenario 5.05 Head-On, Co-Altitude

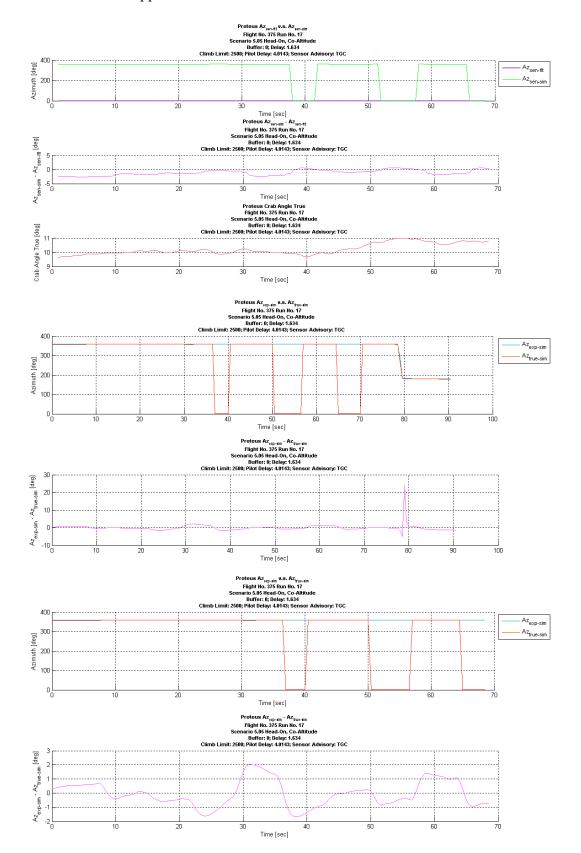
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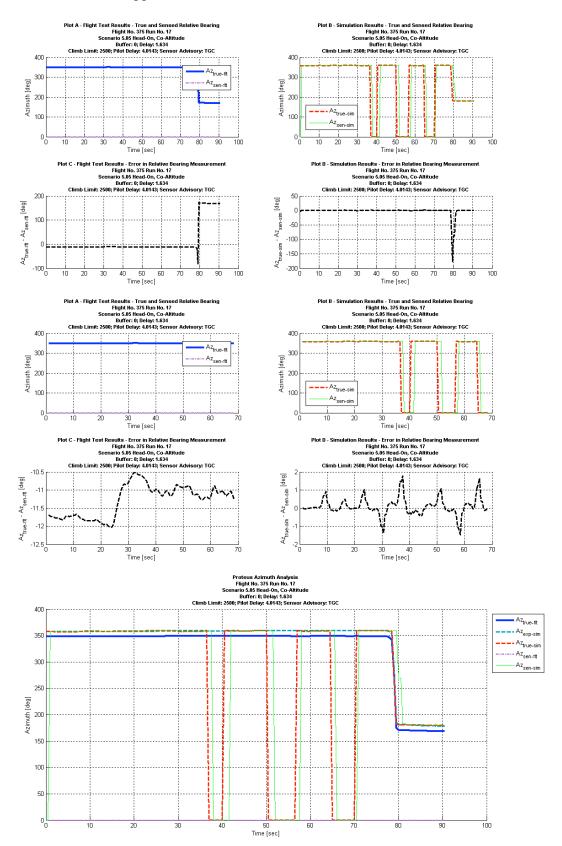


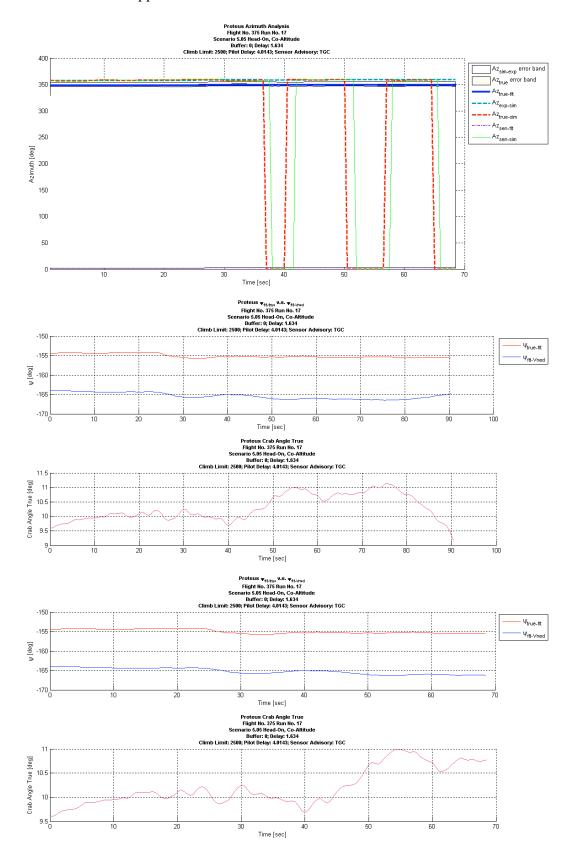


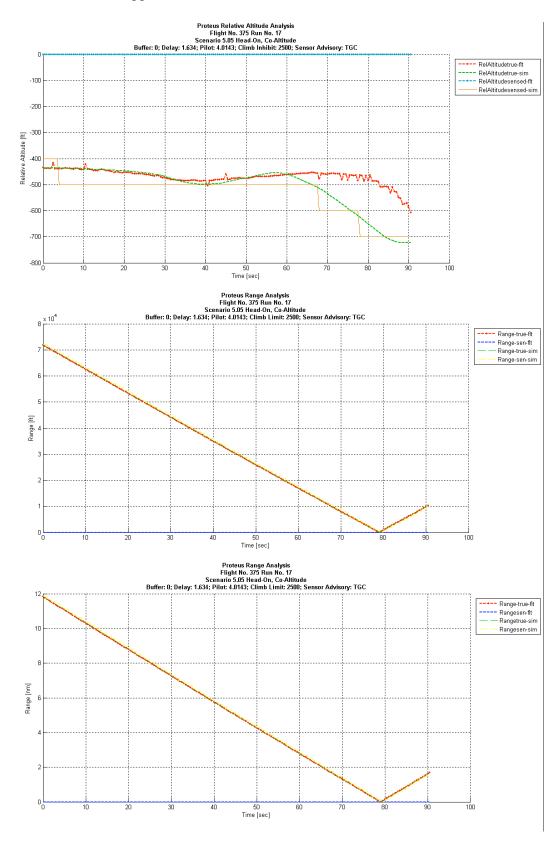




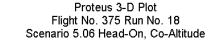




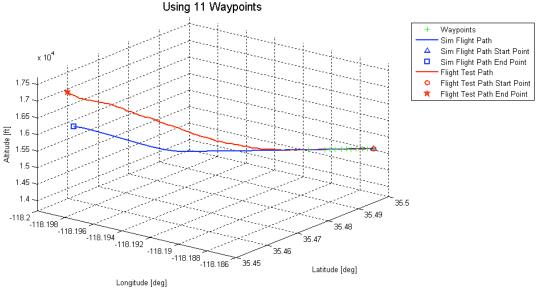




Flight 375 Run 18

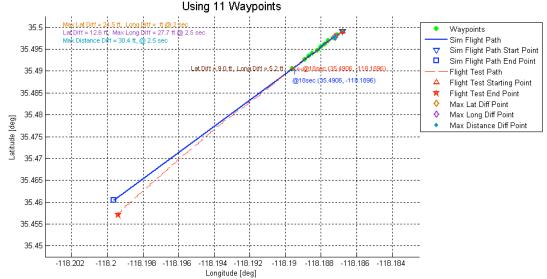


Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC



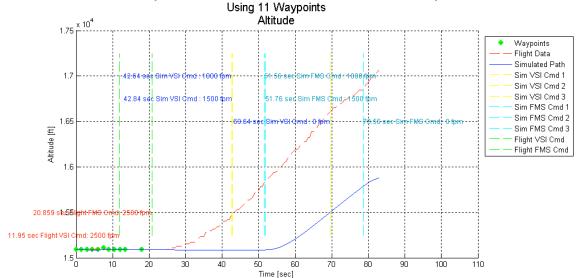
Proteus Flight Path Position Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC



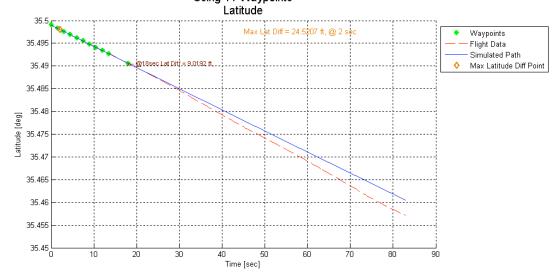
Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

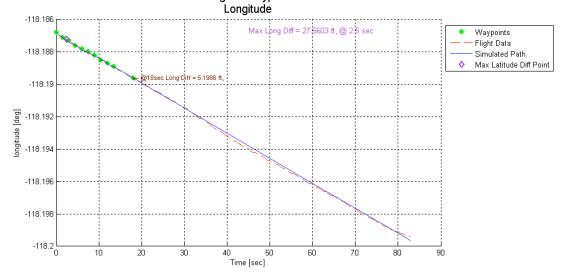
Heading Waypoints Flight Data -156 Simulated Path -158 -160 Heading [deg] -164 -166 -170 L 40 Time [sec] 10 20 30 70

Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints



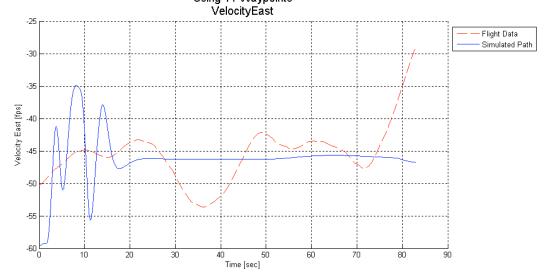
Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude



Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC

> Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude



Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

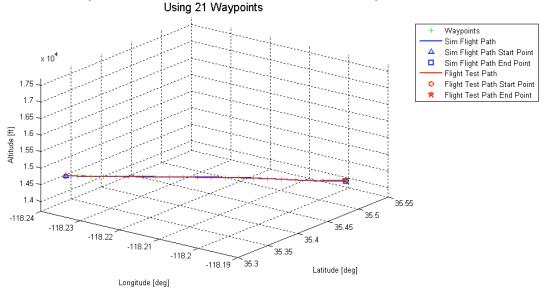
Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

> Proteus Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

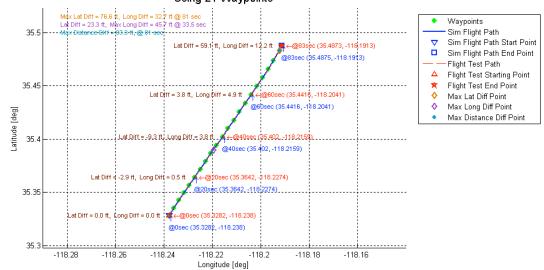
Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

Generic G-III 3-D Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Inhibit: 2500; Sensor Advisory: TGC

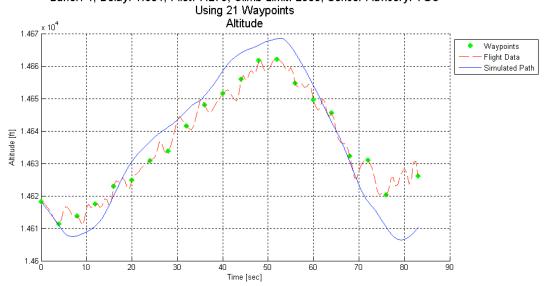


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude



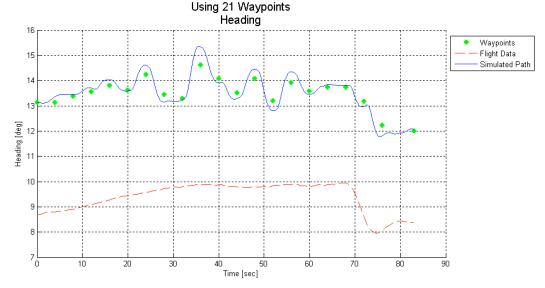
Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC



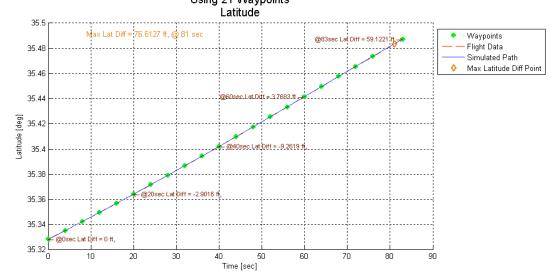
Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC

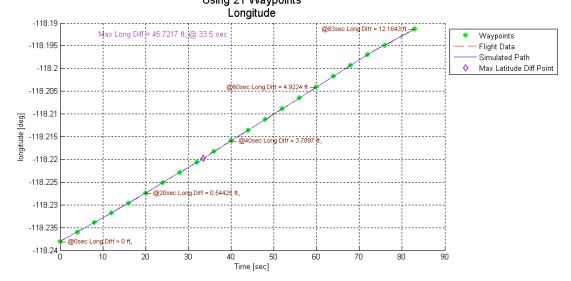


Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC Using 21 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude



Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC

Using 21 Waypoints
VelocityDown

Flight Data
Simulated Path

Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC Using 21 Waypoints

VelocityEast

186

Flight Data
Simulated Path

175

160

155

150

145

100

20

30

40

50

60

70

80

90

Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

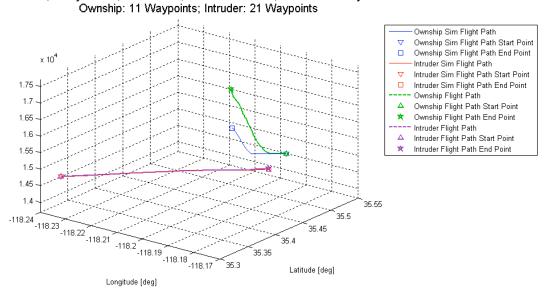
Buffer: 4; Delay: 1.634; Pilot: 7.275; Climb Limit: 2500; Sensor Advisory: TGC

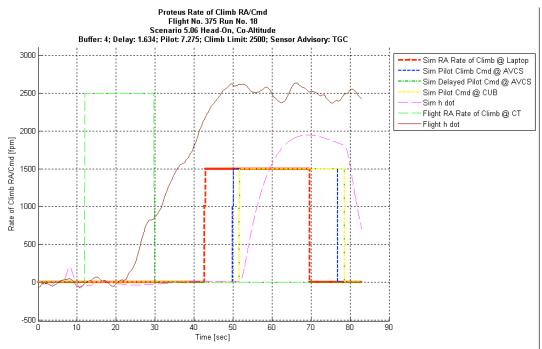
> Generic G-III Time History Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

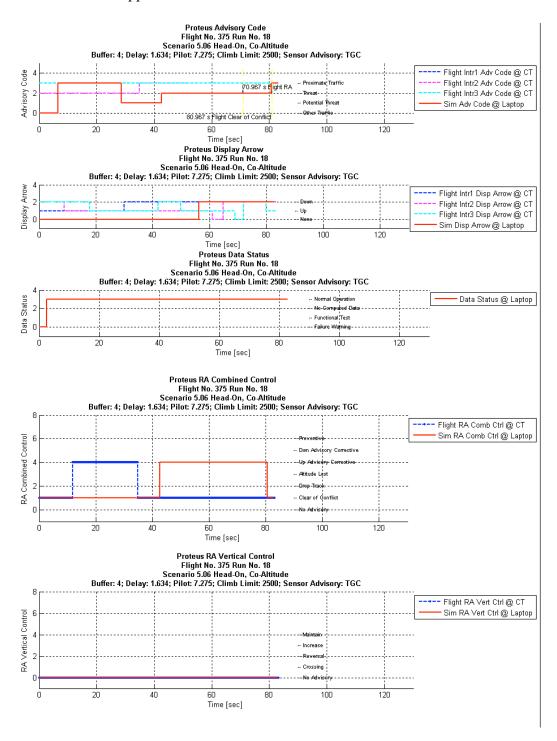
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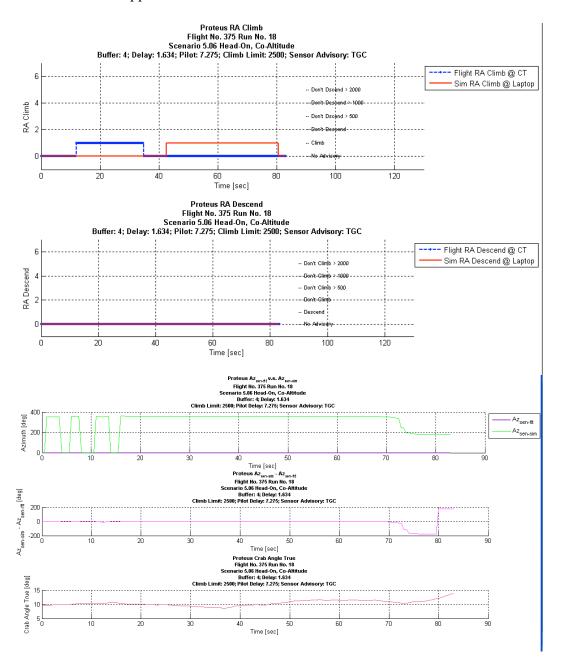
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 18 Scenario 5.06 Head-On, Co-Altitude

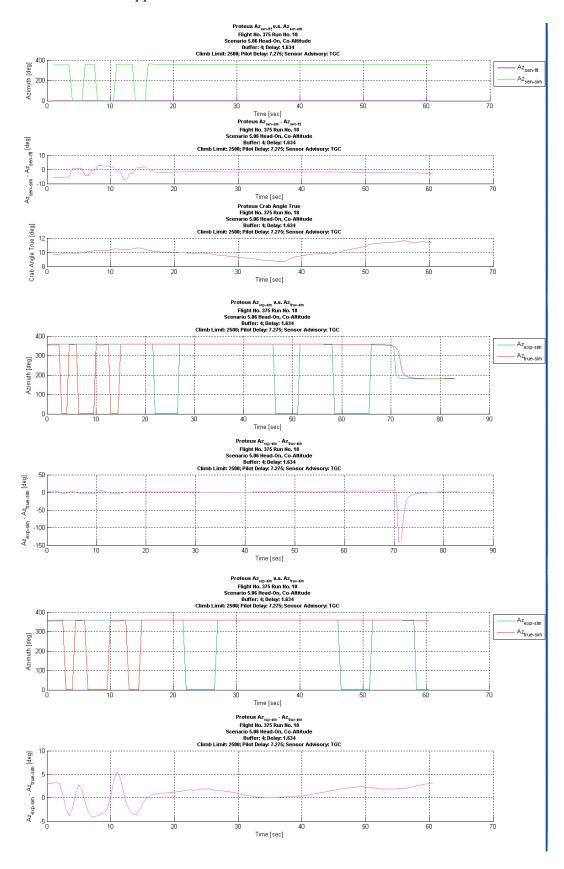
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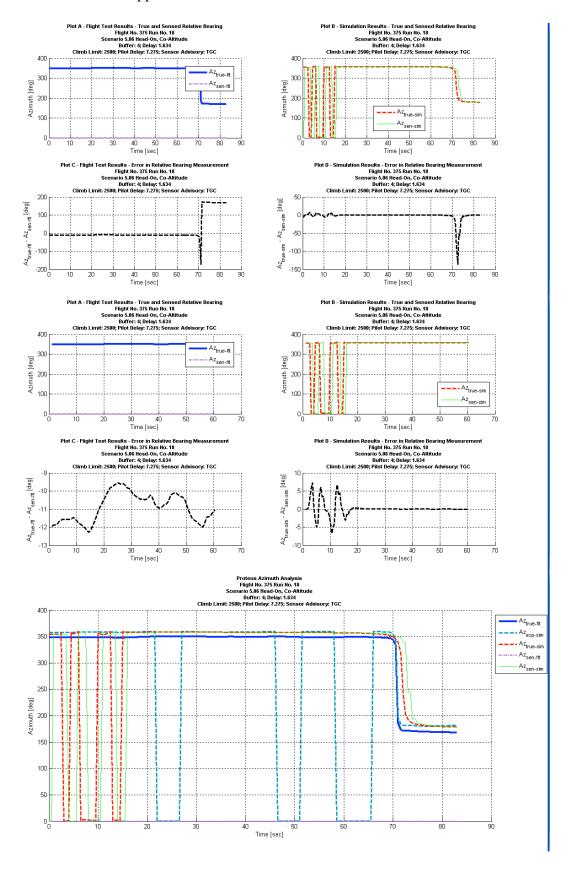


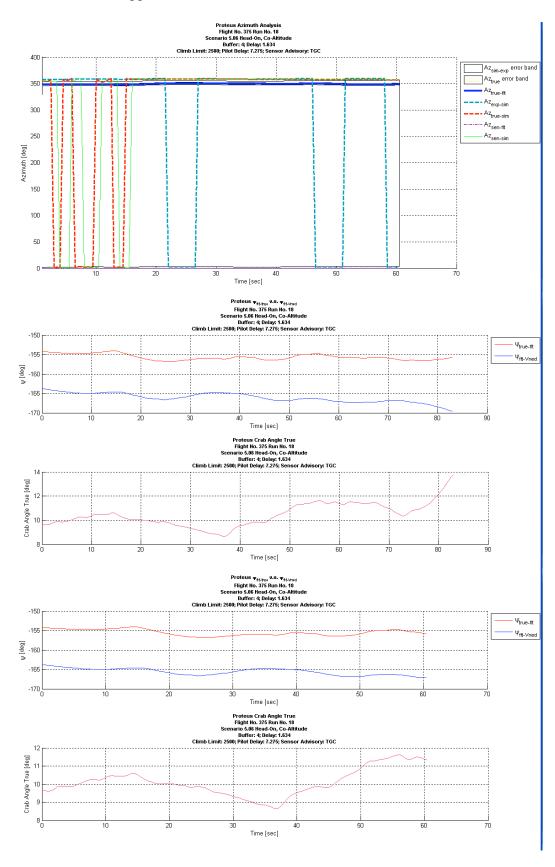


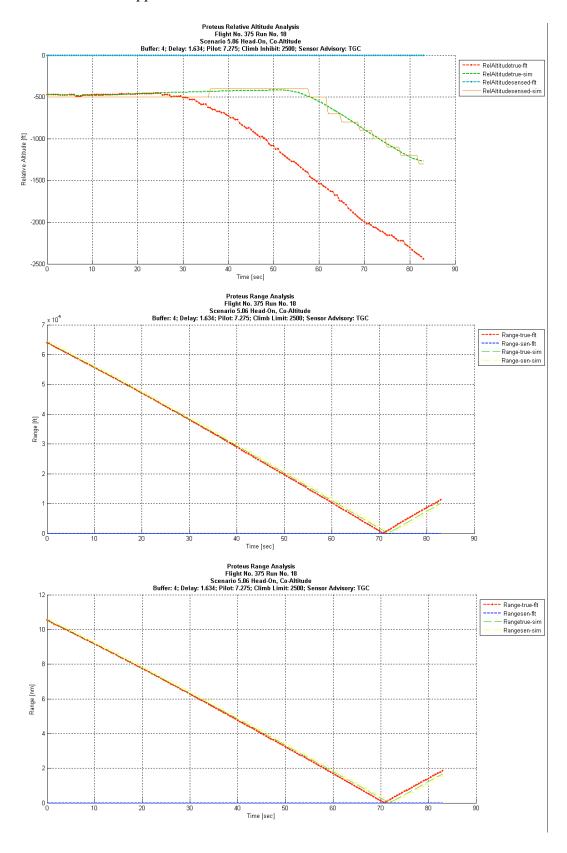






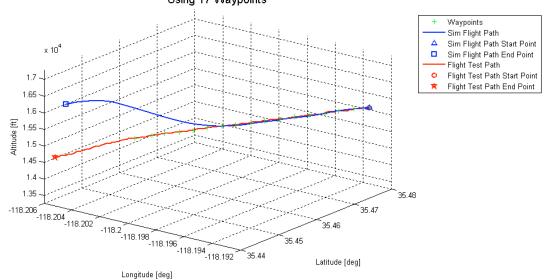






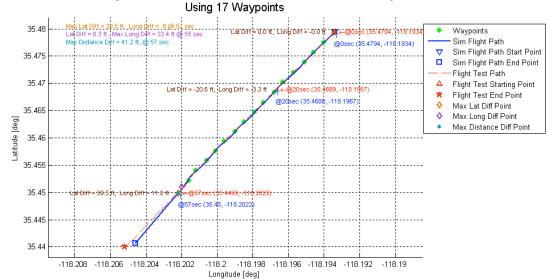
Flight 375 Run 19

Proteus 3-D Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 17 Waypoints



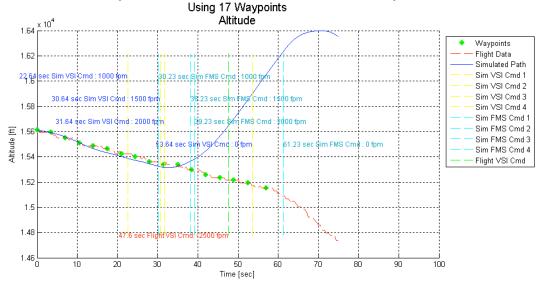
Proteus Flight Path Position Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



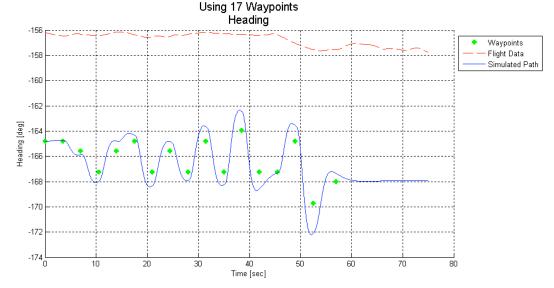
Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

> Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

60

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 17 Waypoints

Time [sec]

35.44 L

Longitude -118.192 Waypoints Flight Data -118.194 Simulated Path Max Latitude Diff Point -118.196 longitude [deg] -118.198 -118.2-118.202 -118.204 -118.206 L 10 20 30 60 70 80 Time [sec]

Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

Using 17 Waypoints
VelocityDown

Flight Data
Simulated Path

Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 17 Waypoints

Time [sec]

-50 L

VelocityEast

-25
-30
-40
-40
-40
-50
-50
-50
-60
-60
-70
-80
-70
-80

Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 17 Waypoints

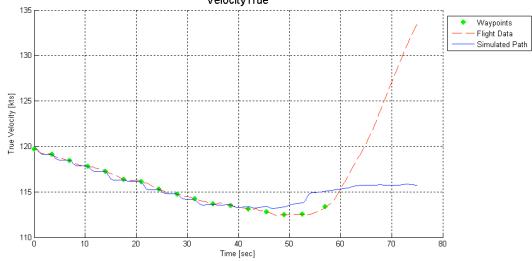
VelocityNorth Flight Data Simulated Path Velocity North [fps] -205 -210 -220 L

> Proteus Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

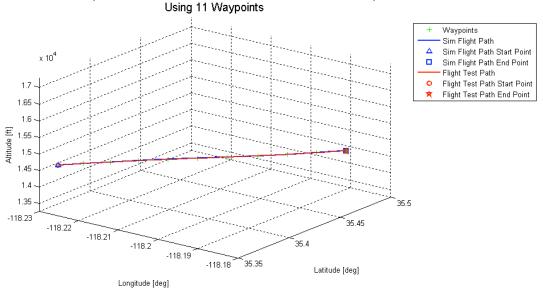
Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 17 Waypoints

Time [sec]

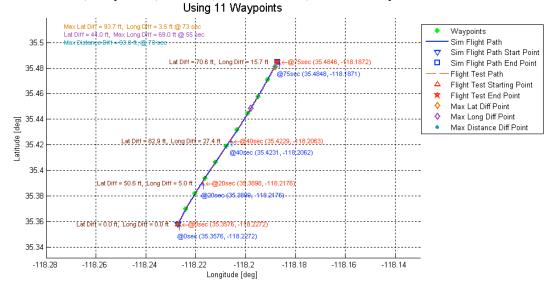
VelocityTrue



Generic G-III 3-D Plot
Flight No. 375 Run No. 19
Scenario 6.01 Head-On, Host Descending
Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Inhibit: 2500; Sensor Advisory: TGC

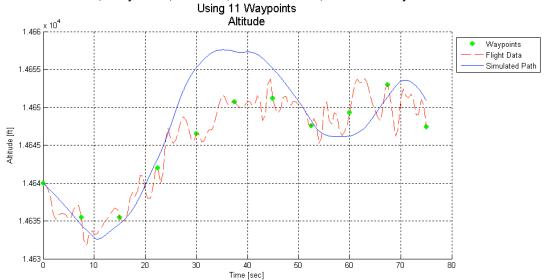


Generic G-III Flight Path Position Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



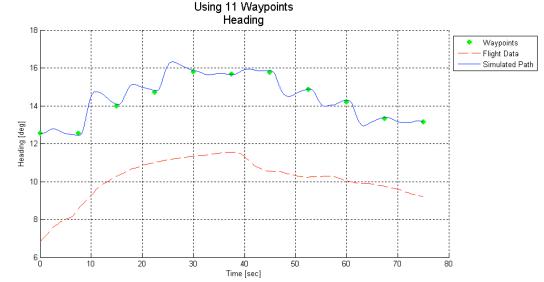
Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



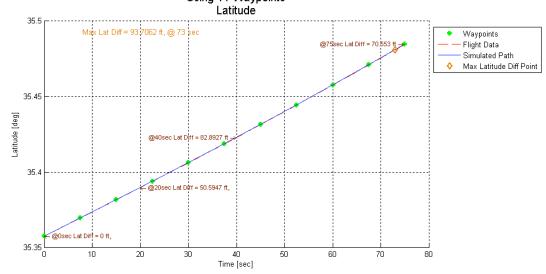
Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



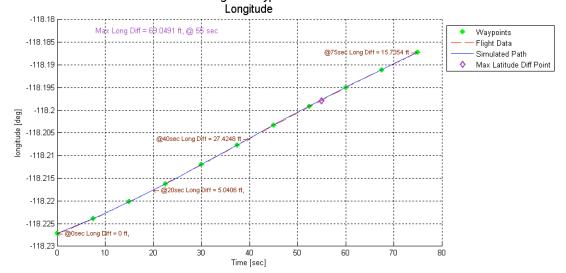
Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

> Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Time [sec]

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

> Generic G-III Time History Plot Flight No. 375 Run No. 19 Scenario 6.01 Head-On, Host Descending

Time [sec]

Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 11 Waypoints

VelocityTrue

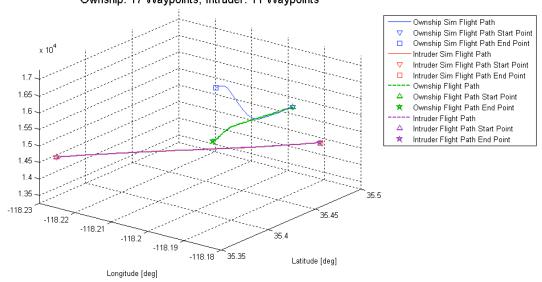
Waypoints
Flight Data
Simulated Path

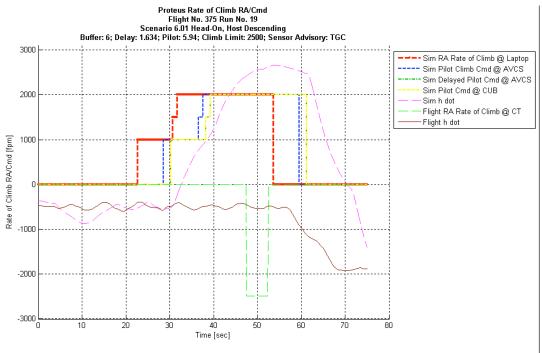
390
360
360
10 20 30 40 50 60 70 80
Time [sec]

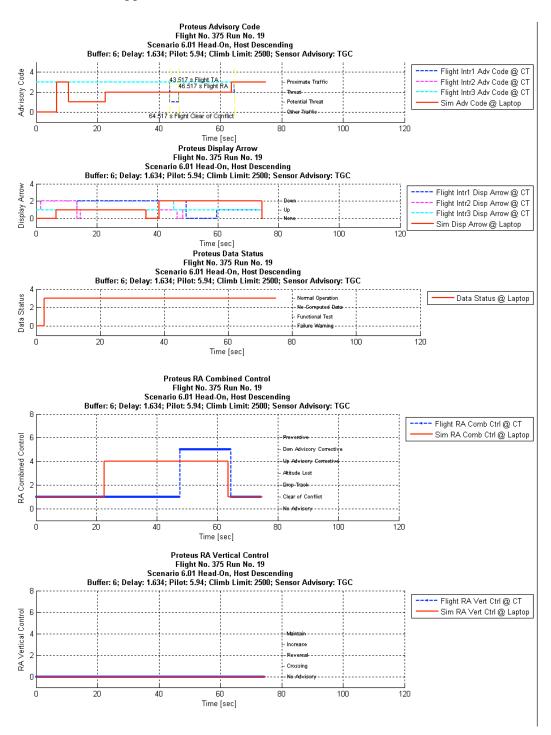
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 19 Genario 6.01 Head-On, Host Descend

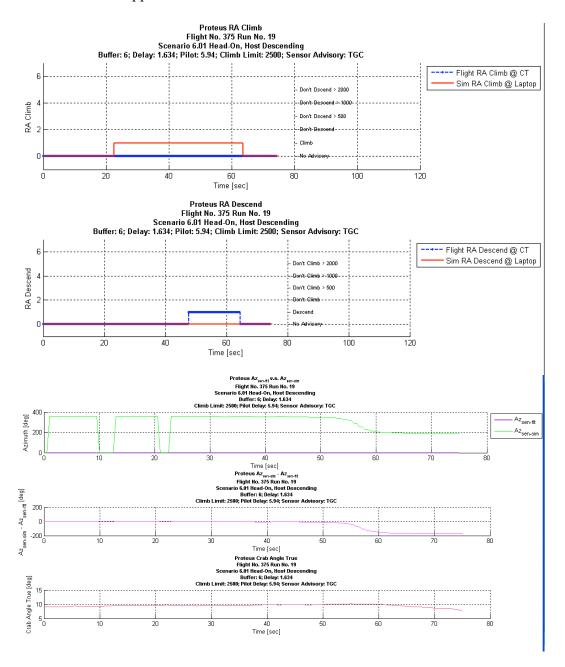
Scenario 6.01 Head-On, Host Descending

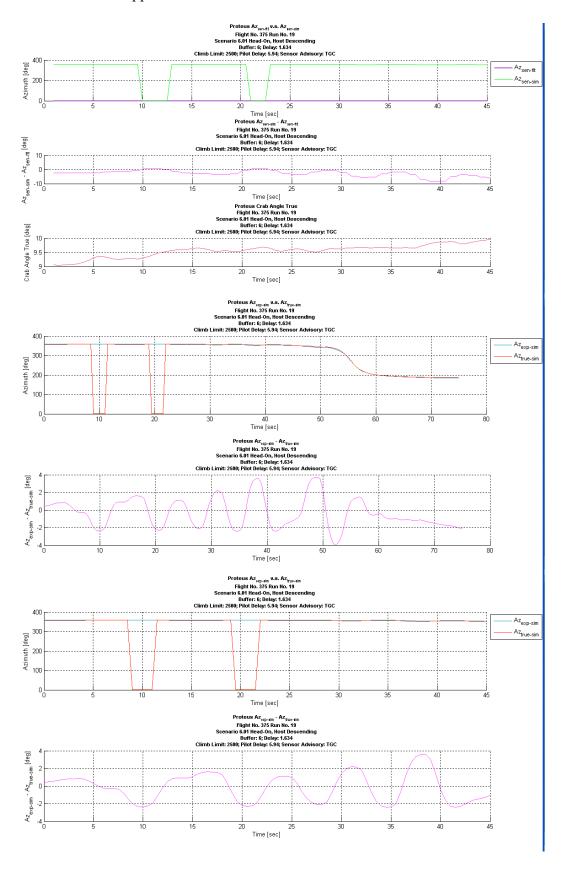
Buffer: 6; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Ownship: 17 Waypoints; Intruder: 11 Waypoints

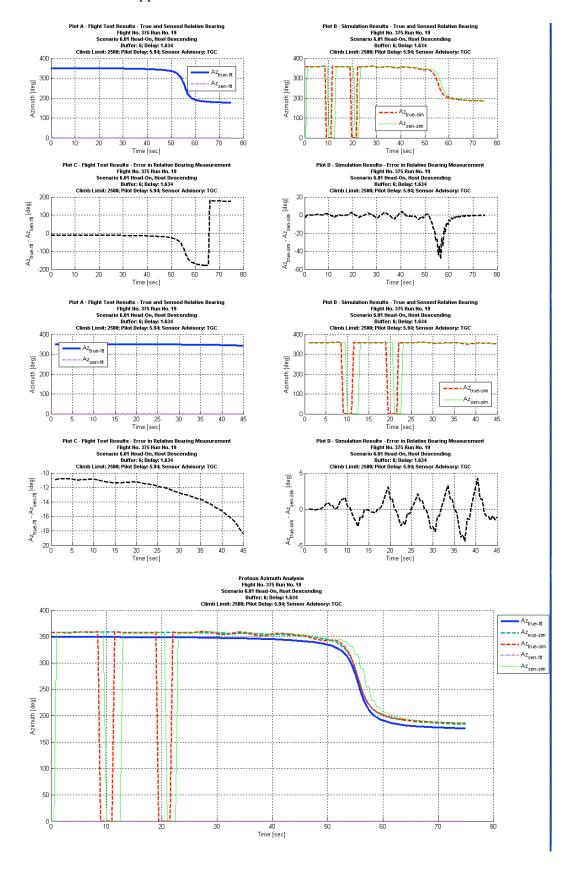


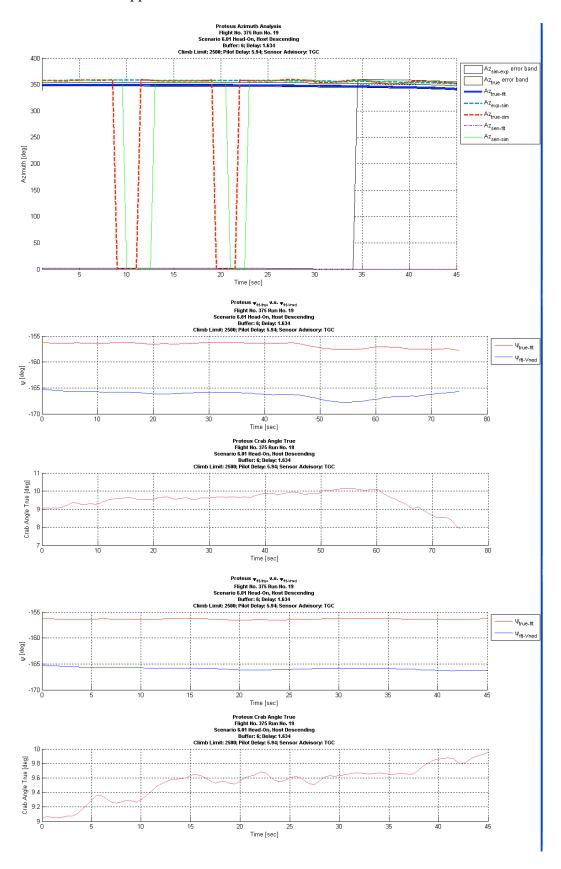


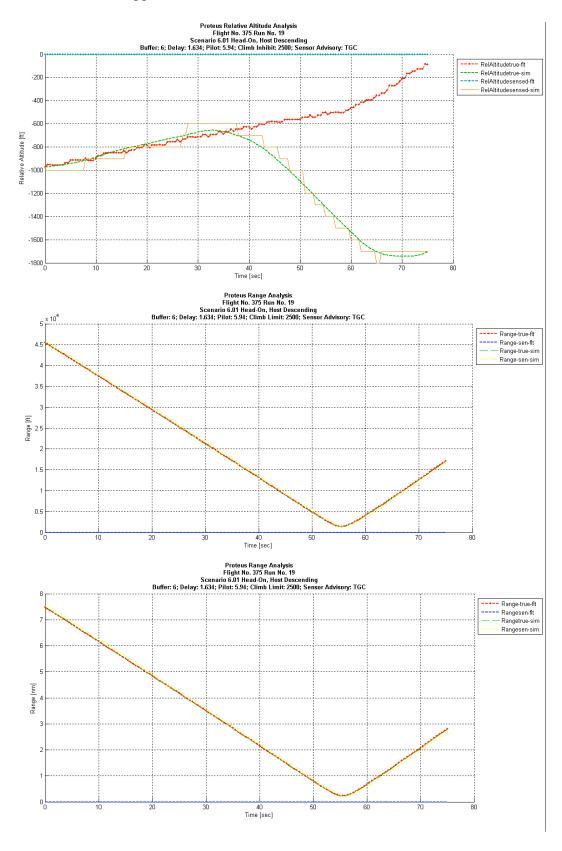








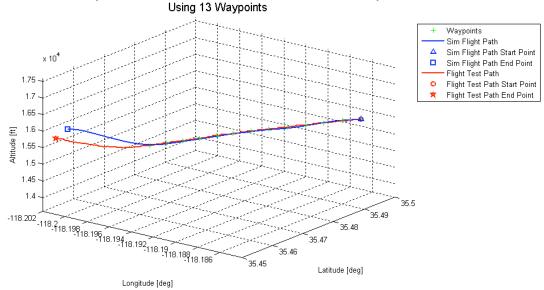




Flight 375 Run 20

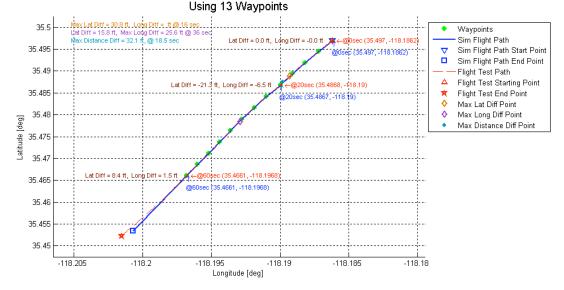
Proteus 3-D Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC



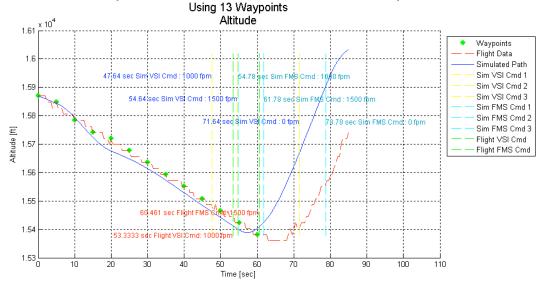
Proteus Flight Path Position Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC



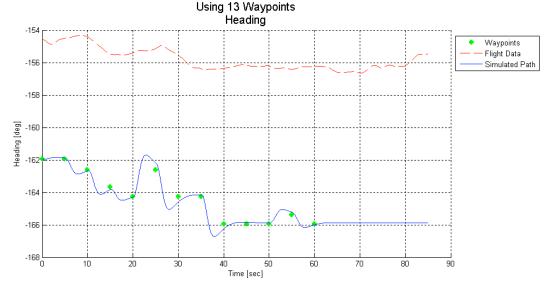
Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC



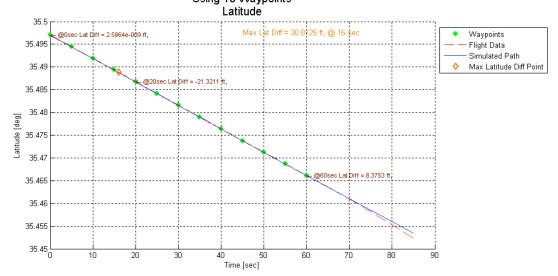
Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC



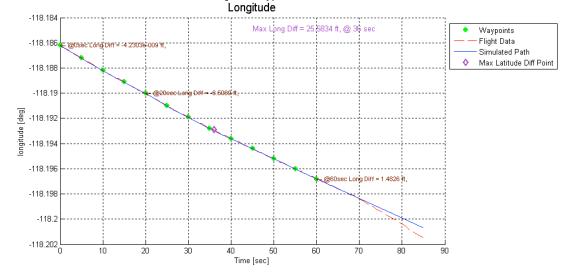
Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC Using 13 Waypoints



Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC Using 13 Waypoints



Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

Using 13 Waypoints VelocityDown Flight Data Simulated Path Velocity Down [fps] -15 -35 L 0

> Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

10

20

30

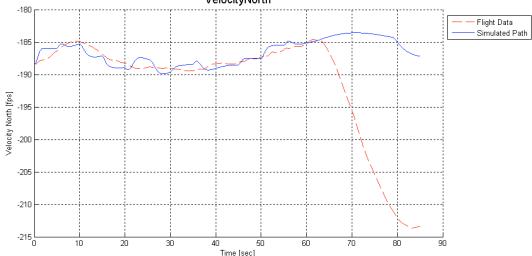
Using 13 Waypoints VelocityEast Flight Data -50 Velocity East [fps] 40 Time [sec]

70

Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

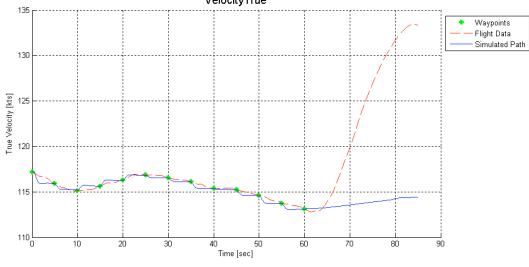
Using 13 Waypoints
VelocityNorth



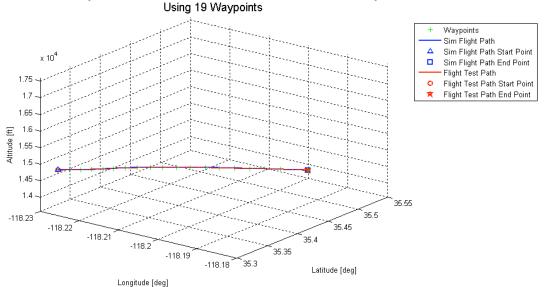
Proteus Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

Using 13 Waypoints VelocityTrue

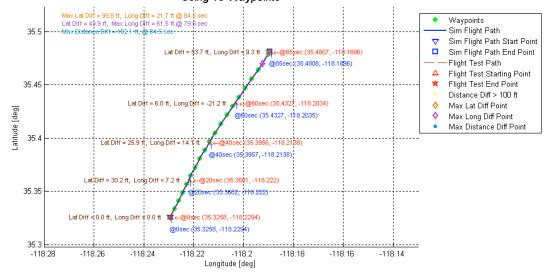


Generic G-III 3-D Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Inhibit: 2500; Sensor Advisory: TGC



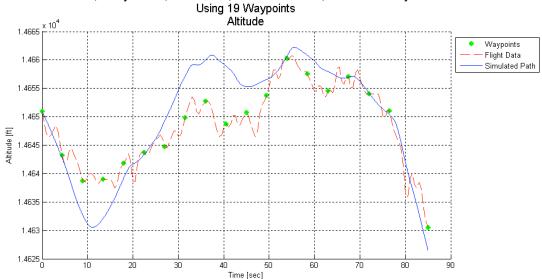
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



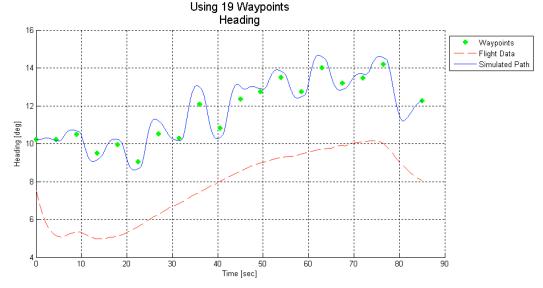
Generic G-III Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC



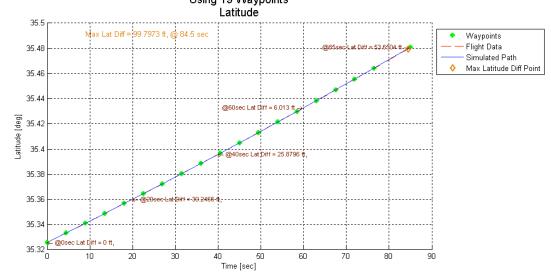
Generic G-III Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC



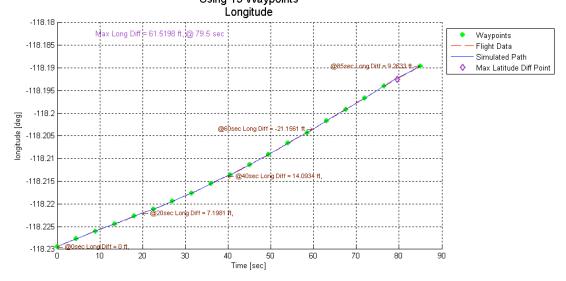
Generic G-III Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints



Generic G-III Time History Plot
Flight No. 375 Run No. 20
Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

Using 19 Waypoints
VelocityDown

Flight Data
Simulated Path

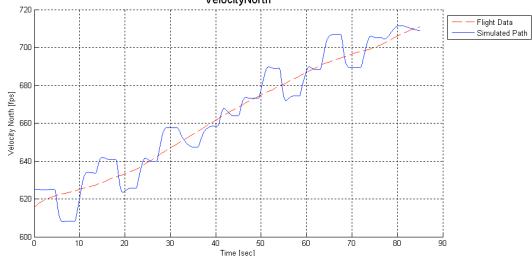
Generic G-III Time History Plot Flight No. 375 Run No. 20 enario 6.05 Head-On, Host Descendin

Scenario 6.05 Head-On, Host Descending Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC Using 19 Waypoints

Generic G-III Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

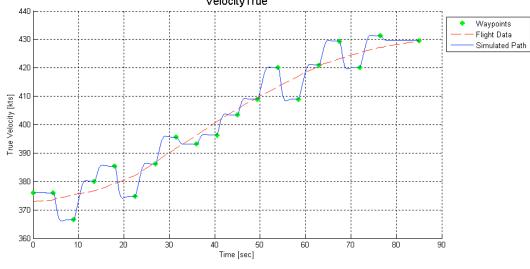
Using 19 Waypoints VelocityNorth



Generic G-III Time History Plot Flight No. 375 Run No. 20 Scenario 6.05 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

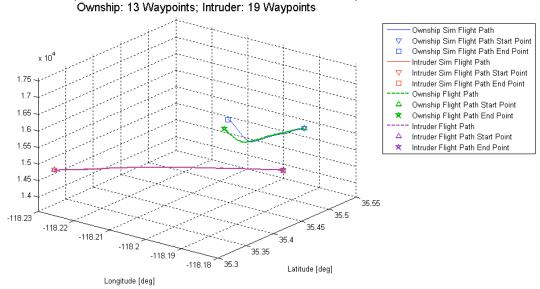
Using 19 Waypoints VelocityTrue

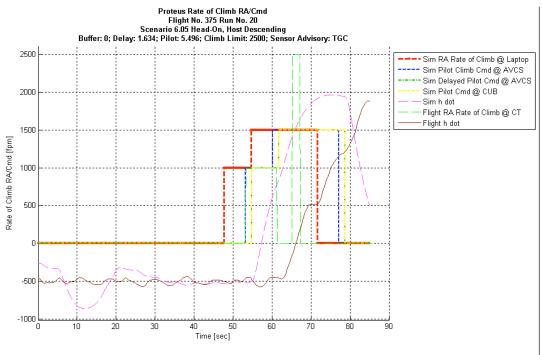


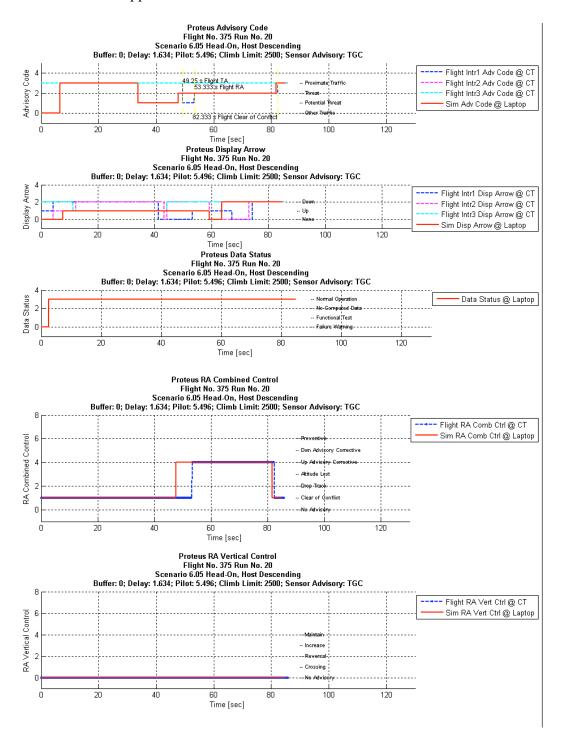
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 20

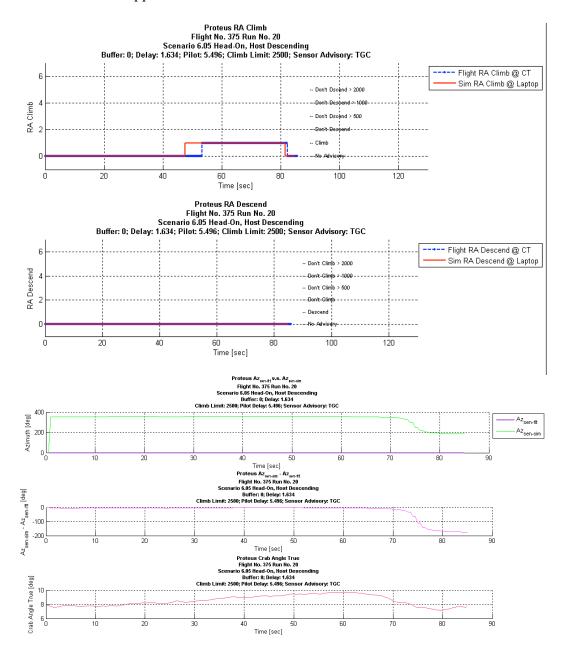
Scenario 6.05 Head-On, Host Descending

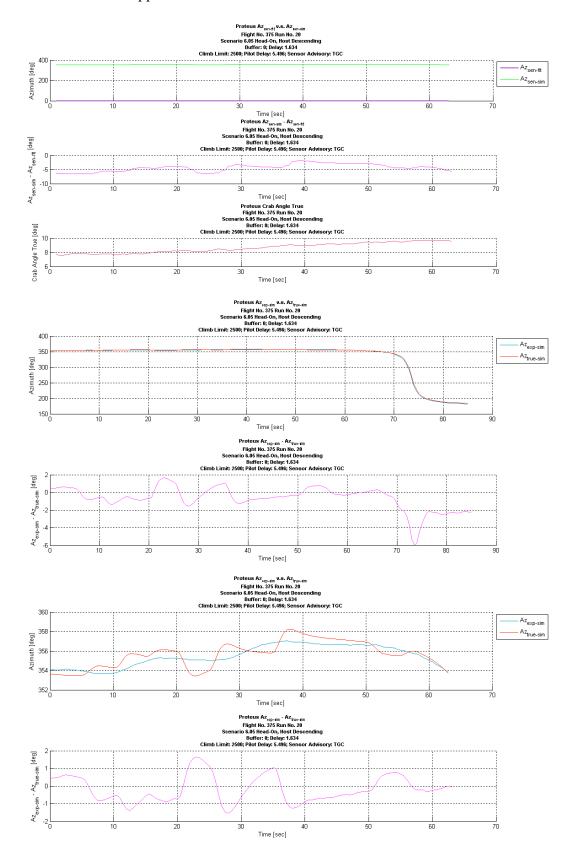
Buffer: 0; Delay: 1.634; Pilot: 5.496; Climb Limit: 2500; Sensor Advisory: TGC

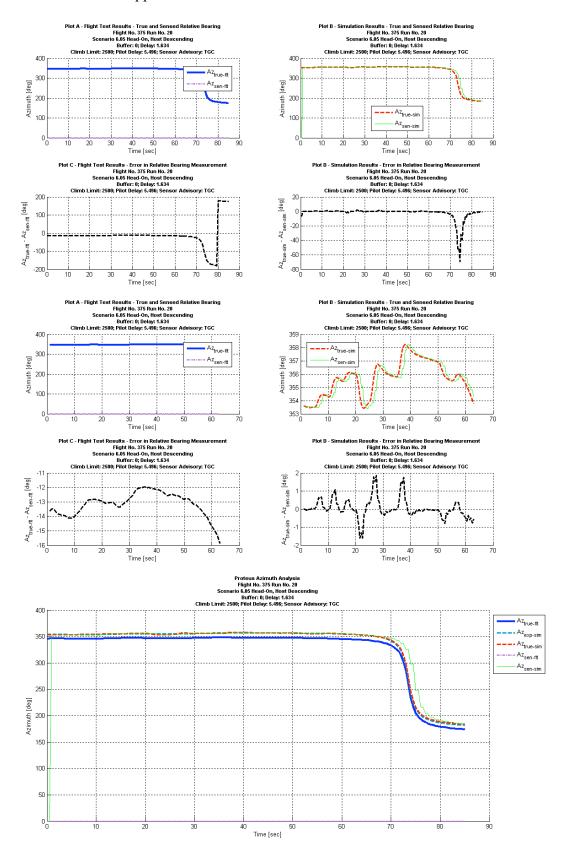


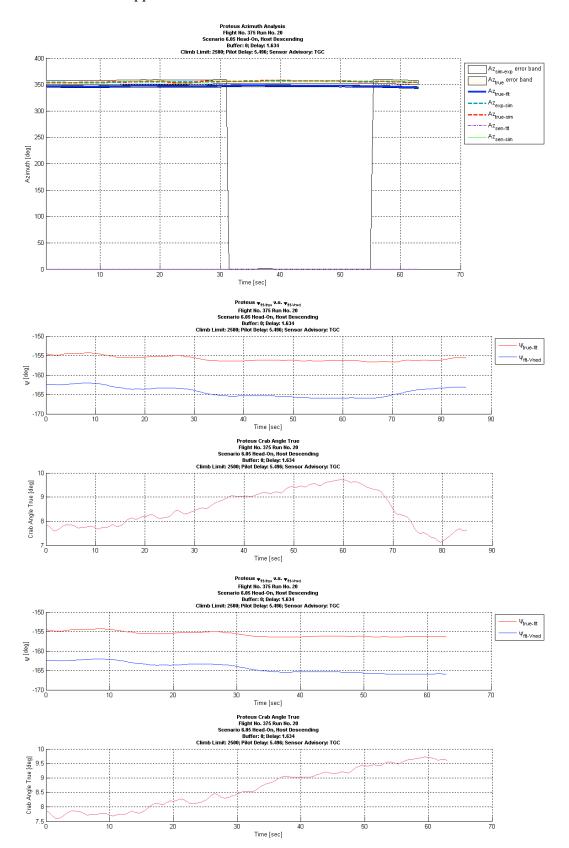


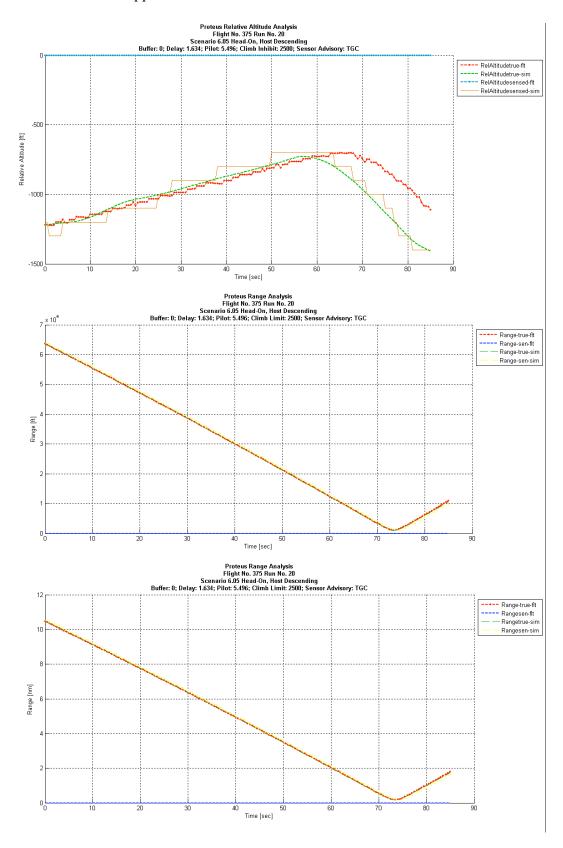






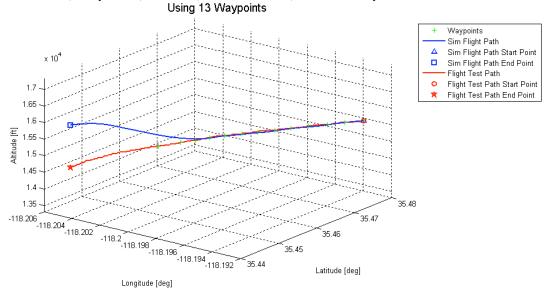






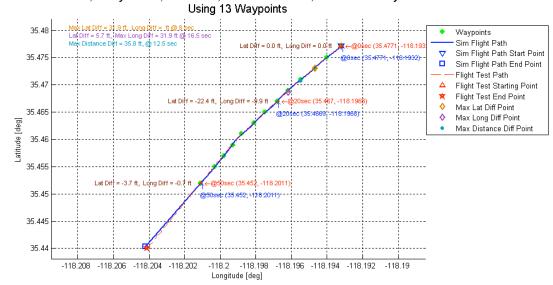
Flight 375 Run 21

Proteus 3-D Plot
Flight No. 375 Run No. 21
Scenario 6.06 Head-On, Host Descending
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



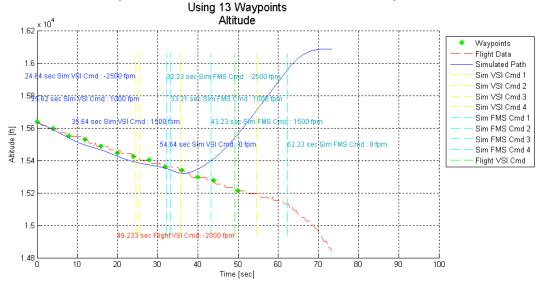
Flight No. 375 Run No. 21
Scenario 6.06 Head-On, Host Descending
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

Proteus Flight Path Position Plot



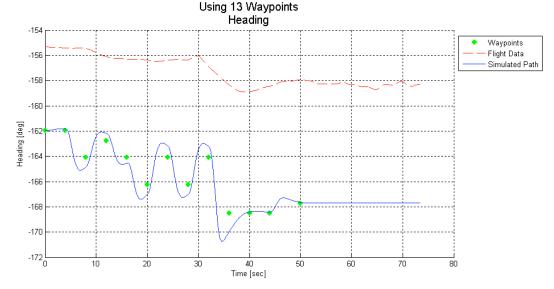
Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

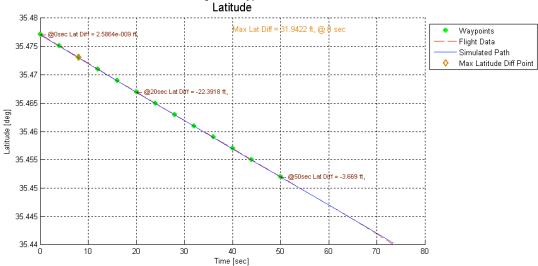
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

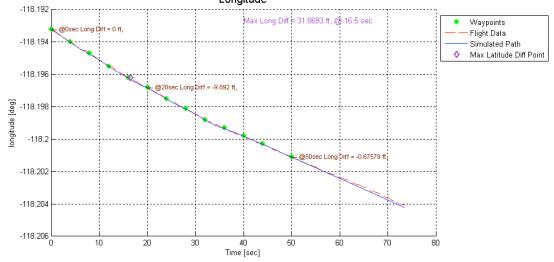
Using 13 Waypoints



Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

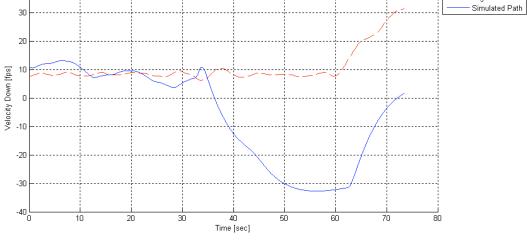
Using 13 Waypoints Longitude



Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

Using 13 Waypoints VelocityDown



Flight Data

Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 13 Waypoints

VelocityEast Flight Data Velocity East [fps] -55 -60 -65 L 10 20 30 40 70 Time [sec]

Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

Using 13 Waypoints
VelocityNorth

-175

-180

-180

-195

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Proteus Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 13 Waypoints

Time [sec]

VelocityTrue

124

122

120

118

118

110

108

100

200

300

400

500

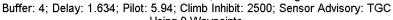
600

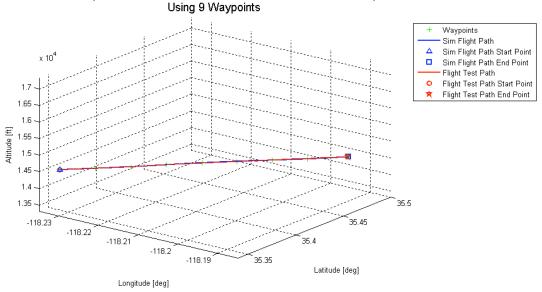
700

800

Time [sec]

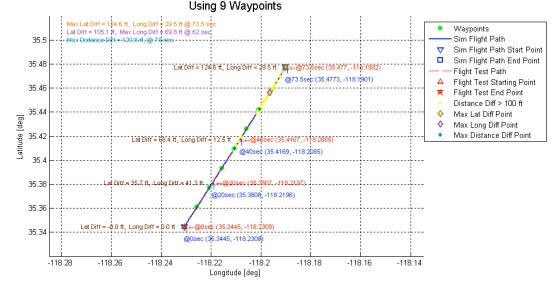
Generic G-III 3-D Plot
Flight No. 375 Run No. 21
Scenario 6.06 Head-On, Host Descending
v: 1.634: Pilot: 5.94: Climb Inhibit: 2500: Sensor Advi





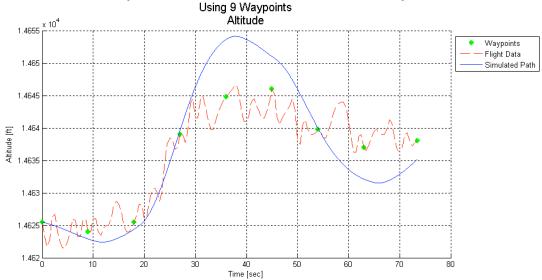
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



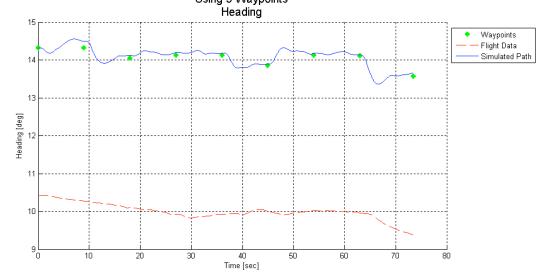
Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

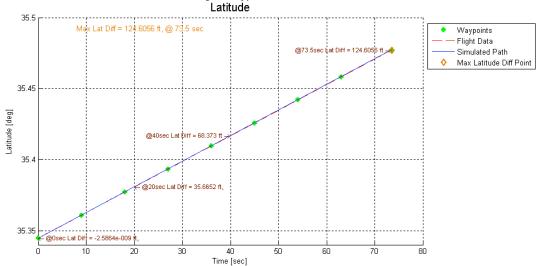
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 9 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

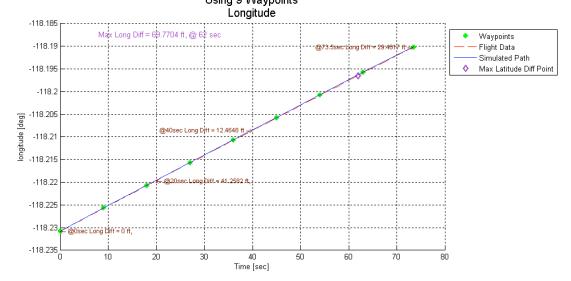
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

Using 9 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 9 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

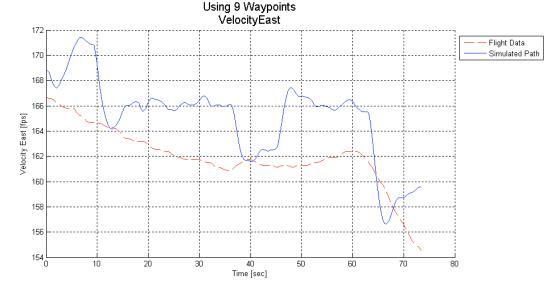
Using 9 Waypoints
VelocityDown

Flight Data
Simulated Path

Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Time [sec]

Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC



Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

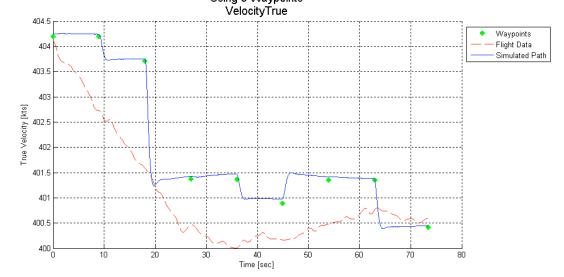
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC

> Generic G-III Time History Plot Flight No. 375 Run No. 21 Scenario 6.06 Head-On, Host Descending

Time [sec]

656 L

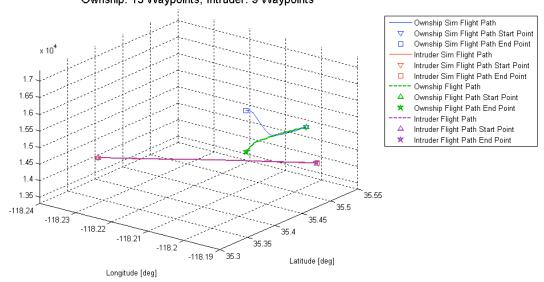
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Using 9 Waypoints

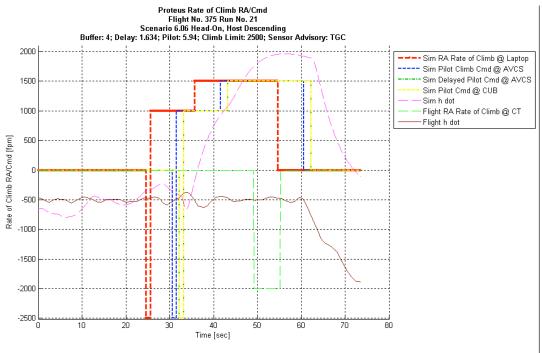


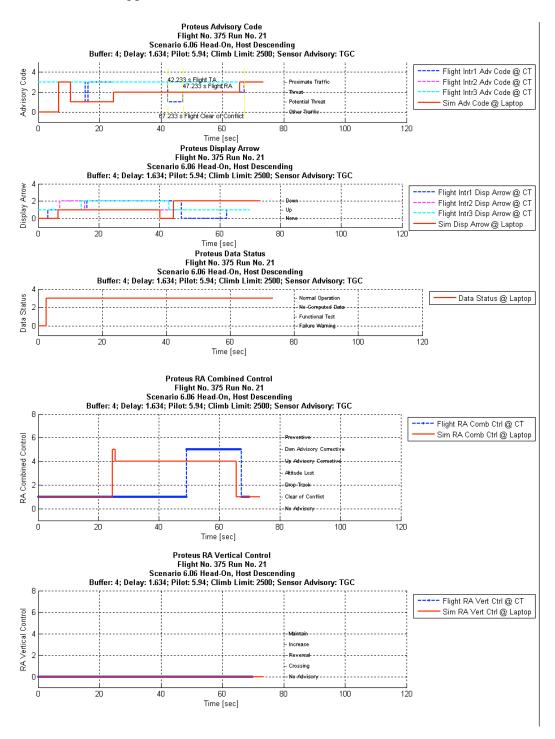
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 21

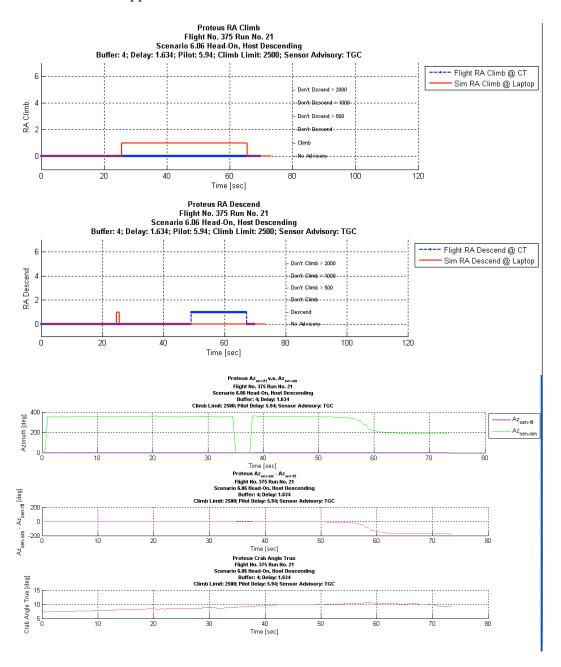
Scenario 6.06 Head-On, Host Descending

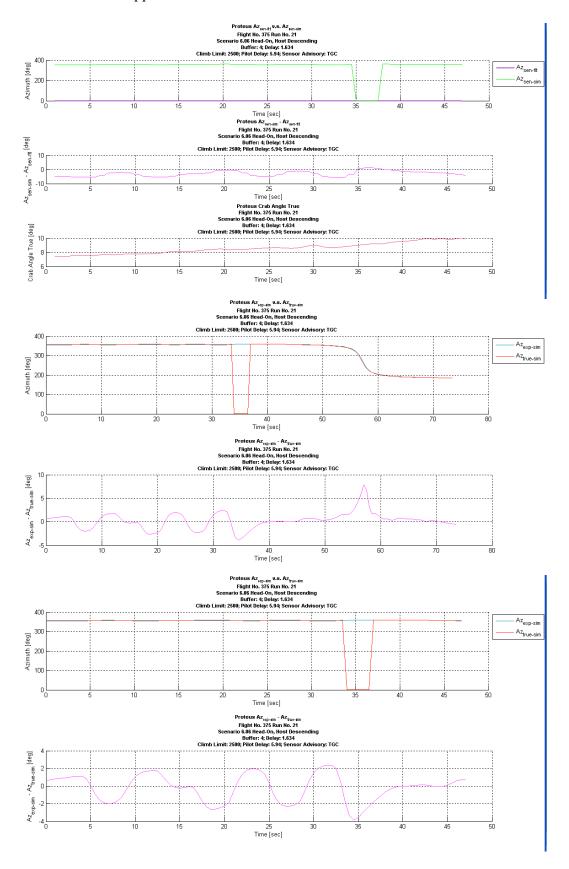
Buffer: 4; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TGC Ownship: 13 Waypoints; Intruder: 9 Waypoints

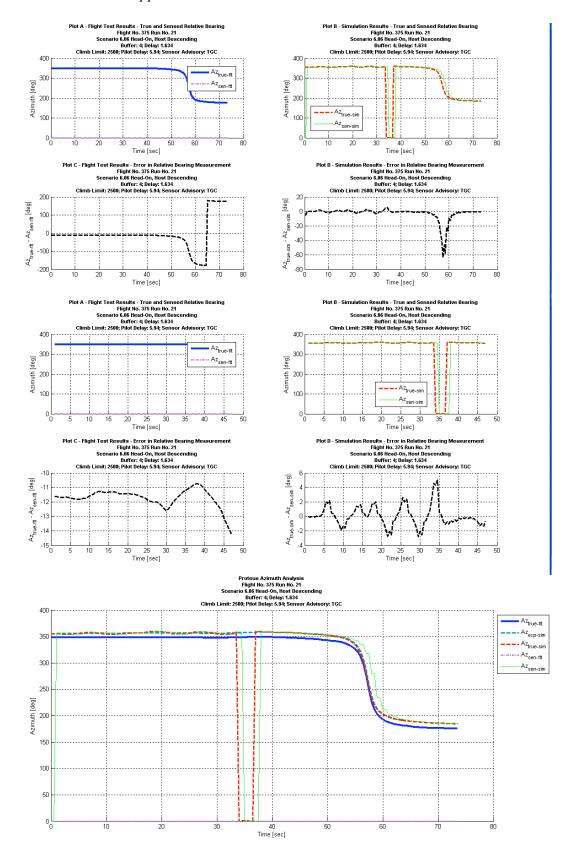


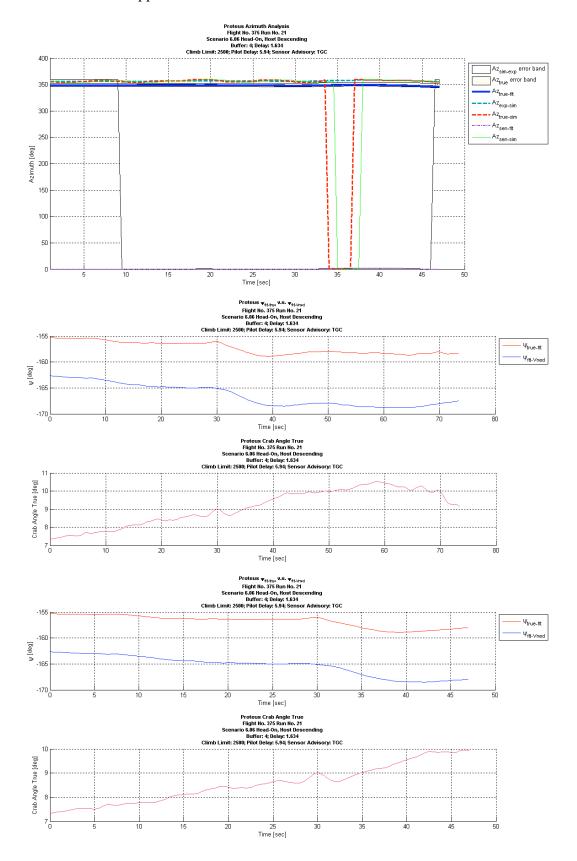


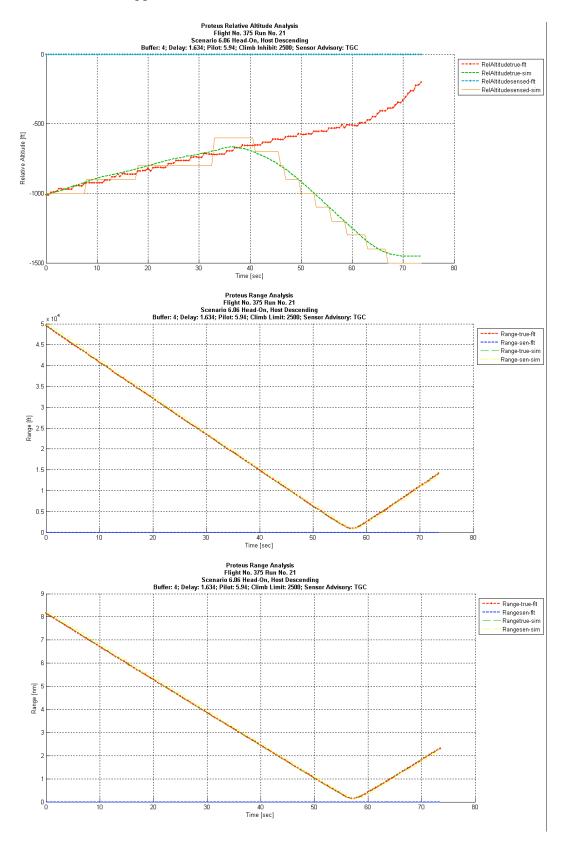








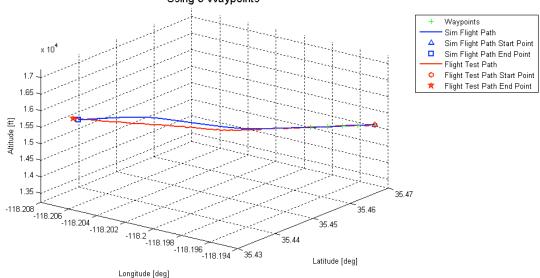




Flight 375 Run 23

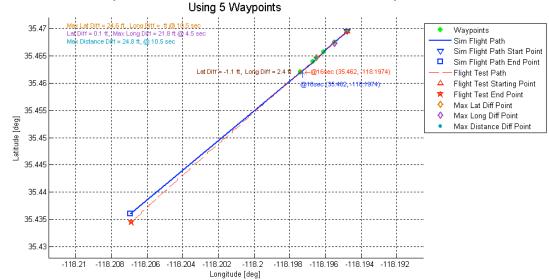
Proteus 3-D Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 5 Waypoints



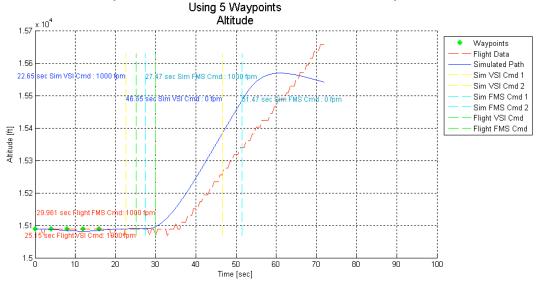
Proteus Flight Path Position Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA



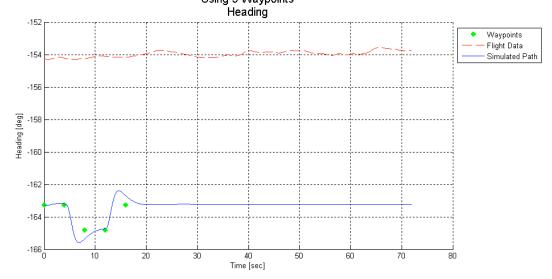
Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA



Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 5 Waypoints

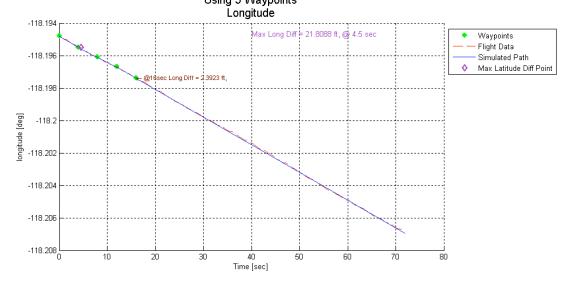


Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 5 Waypoints

> Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

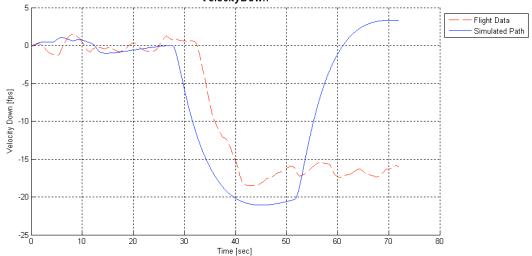
Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 5 Waypoints



Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA

Using 5 Waypoints VelocityDown



Proteus Time History Plot Flight No. 375 Run No. 23 rio 2.02 Low-Aspect. Co-Altitud

Scenario 2.02 Low-Aspect, Co-Altitude
Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA
Using 5 Waypoints

Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

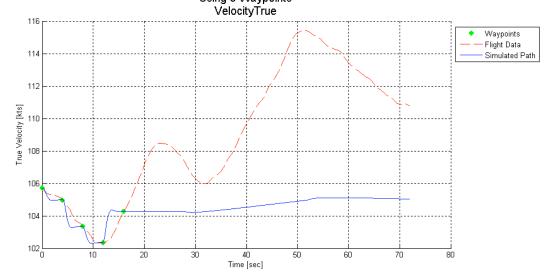
Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA

Using 5 Waypoints
VelocityNorth

——Flight Data
——Simulated Path
——Simulated Path
——Simulated Path
——Thight Data
——Simulated Path
——Flight Data
——Simulated Path
——Thight Data
——Thigh

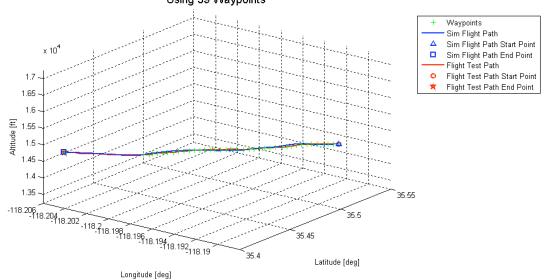
Proteus Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 5 Waypoints



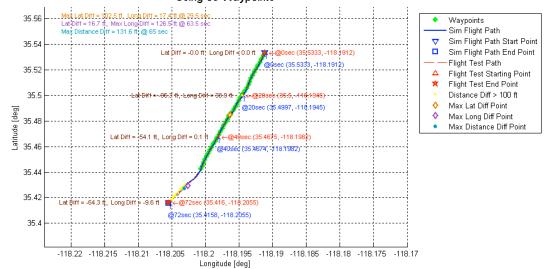
Generic G-III 3-D Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Inhibit: 1000; Sensor Advisory: AGA Using 39 Waypoints



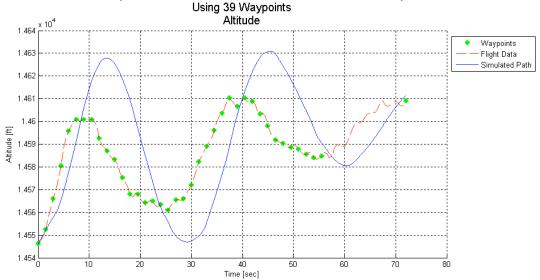
Generic G-III Flight Path Position Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 39 Waypoints



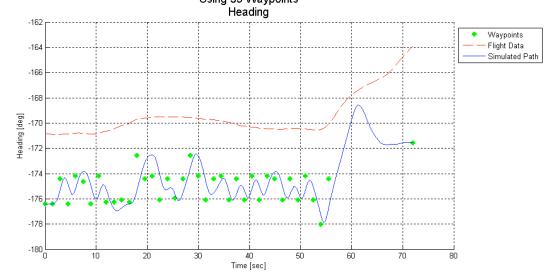
Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA



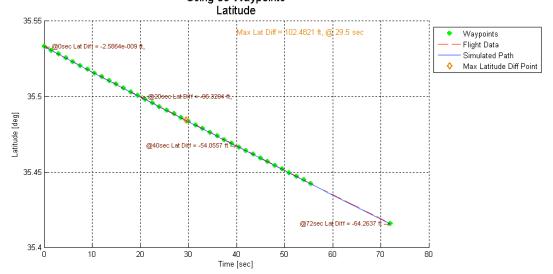
Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 39 Waypoints



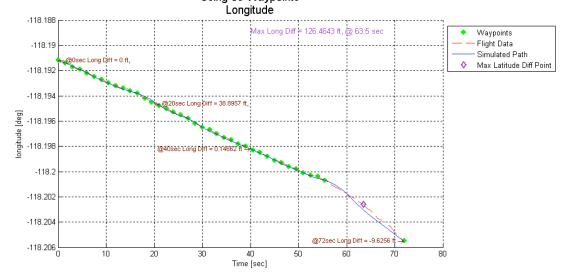
Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 39 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 39 Waypoints



Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA

Using 39 Waypoints
VelocityDown

Flight Data
Simulated Path

Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Time [sec]

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 39 Waypoints

Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA

Using 39 Waypoints
VelocityNorth

Flight Data
Simulated Path

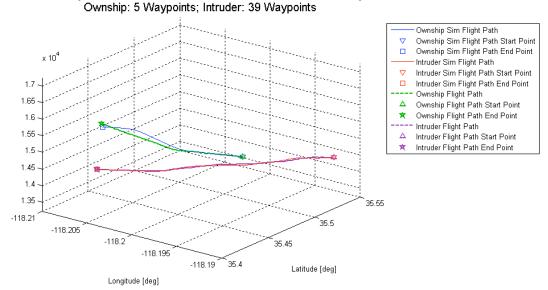
Generic G-III Time History Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

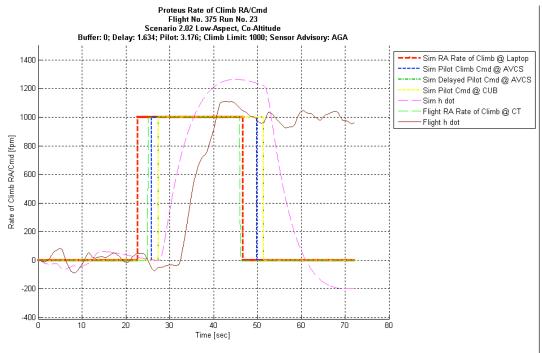
Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA Using 39 Waypoints

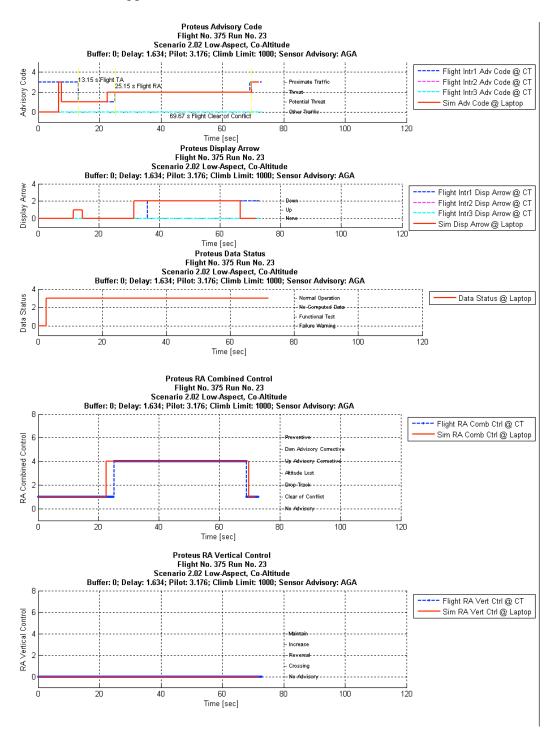
VelocityTrue 380 Waypoints Flight Data Simulated Path 370 365 True Velocity [kts] 360 355 345 10 20 30 70 Time [sec]

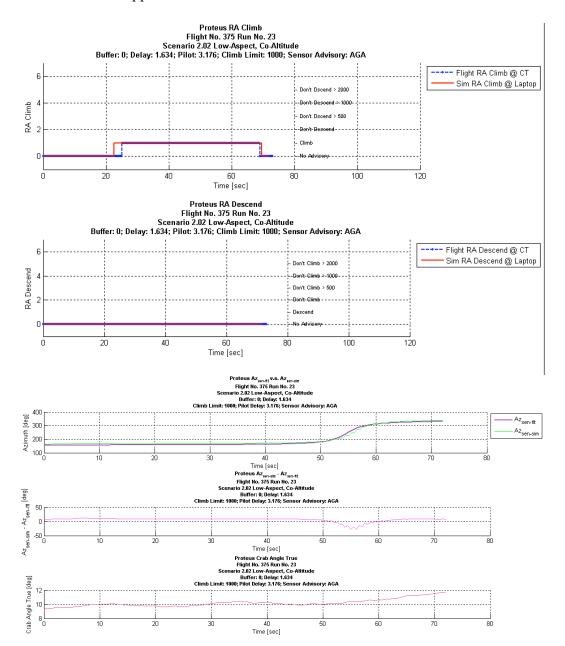
Proteus-Generic G-III 3-D Plot Flight No. 375 Run No. 23 Scenario 2.02 Low-Aspect, Co-Altitude

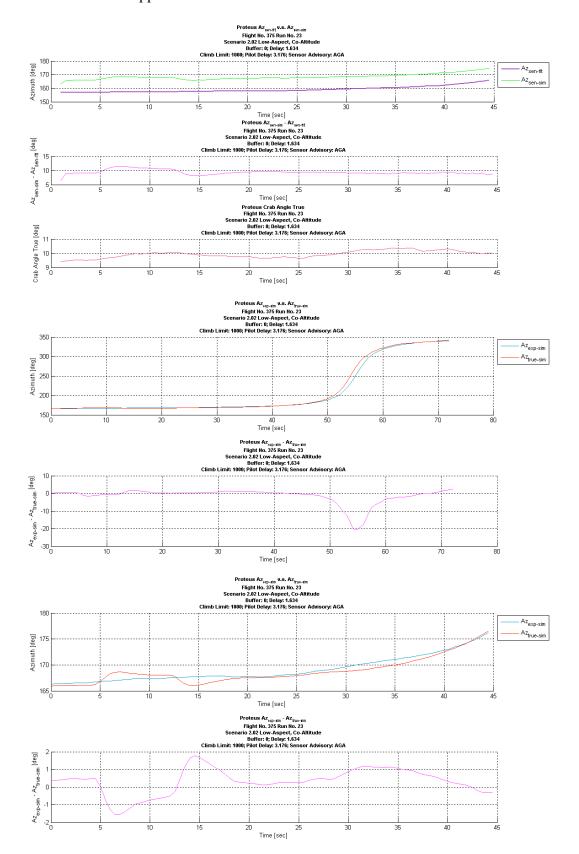
Buffer: 0; Delay: 1.634; Pilot: 3.176; Climb Limit: 1000; Sensor Advisory: AGA

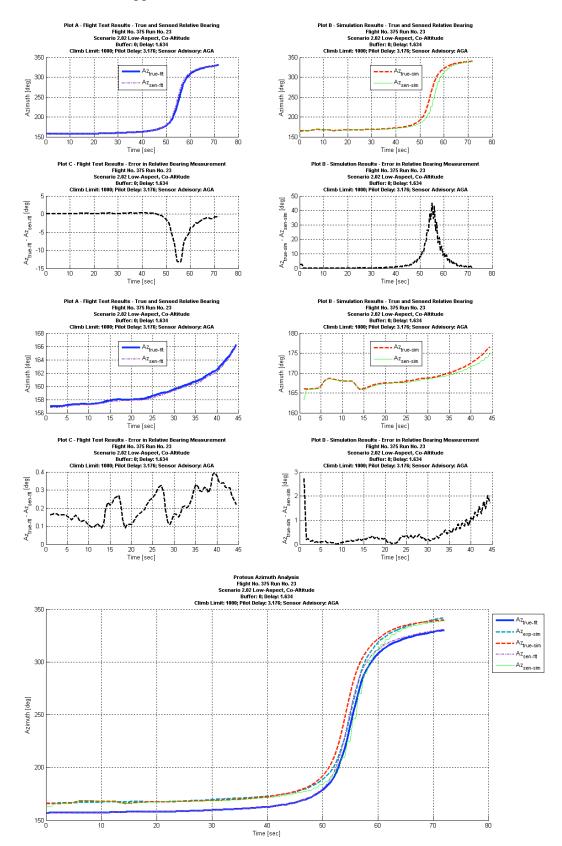


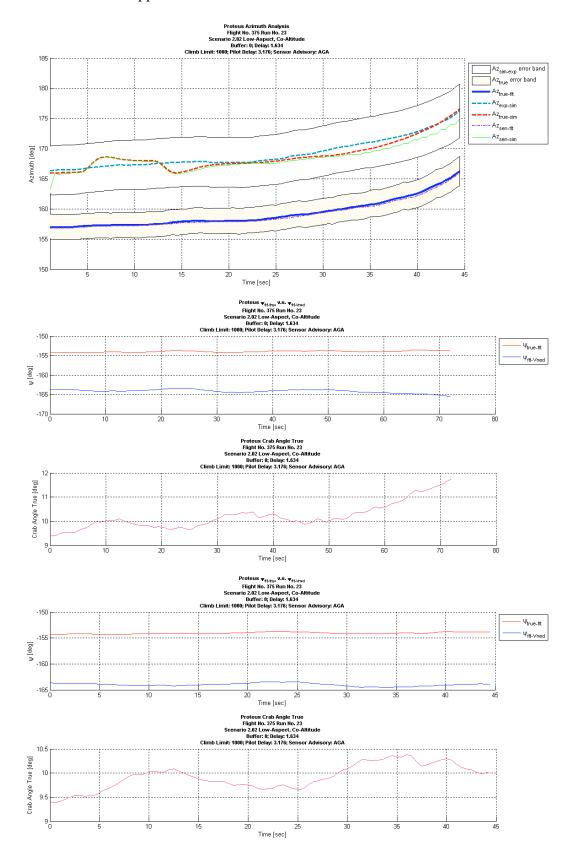


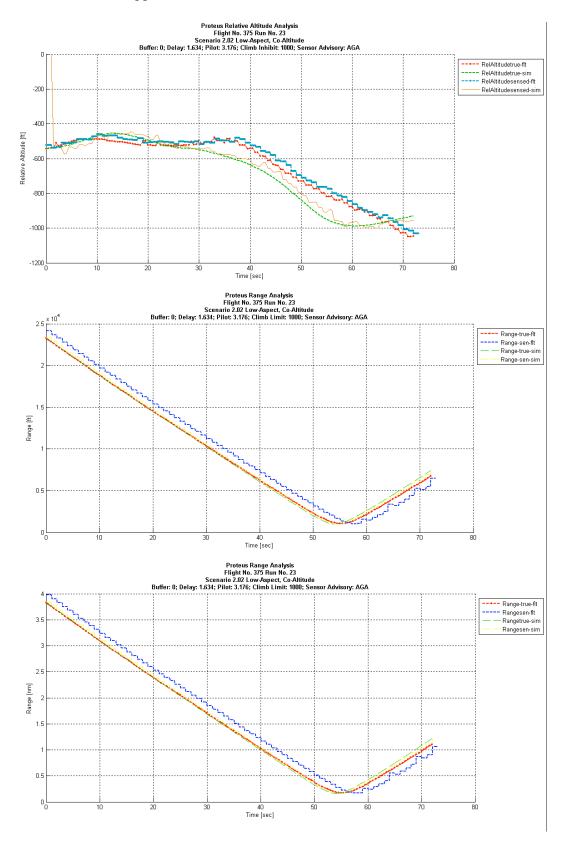






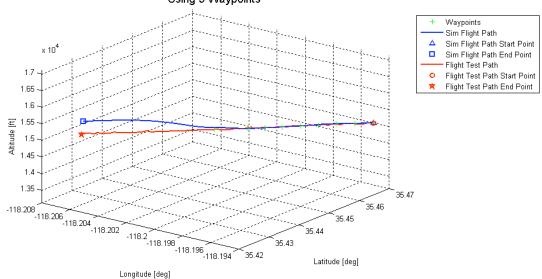




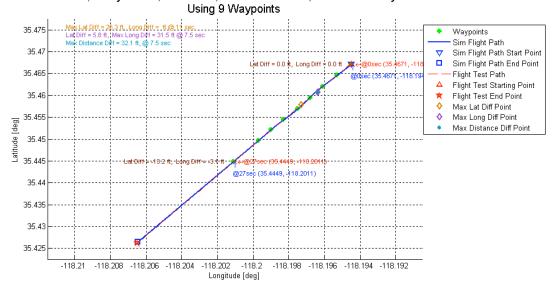


Flight 369 Run 2

Proteus 3-D Plot
Flight No. 369 Run No. 2
Scenario 3.03 Co-Heading, Intruder Climbing
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT
Using 9 Waypoints

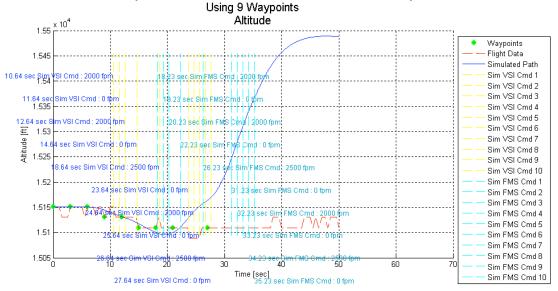


Proteus Flight Path Position Plot
Flight No. 369 Run No. 2
Scenario 3.03 Co-Heading, Intruder Climbing
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Proteus Time History Plot Flight No. 369 Run No. 2 Scenario 3.03 Co-Heading, Intruder Climbing

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Proteus Time History Plot Flight No. 369 Run No. 2 Scenario 3.03 Co-Heading, Intruder Climbing

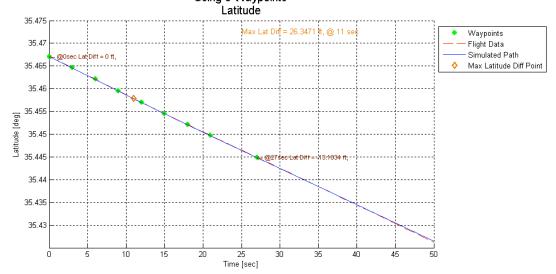
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 9 Waypoints Heading -164 Waypoints Flight Data Simulated Path -165 -165.5 Heading [deg] -167 -167.5 -168 -168.5 -169 L 20 45 50 Time [sec]

Proteus Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing

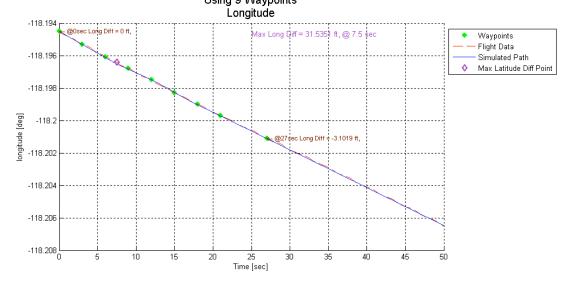
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 9 Waypoints



Proteus Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing

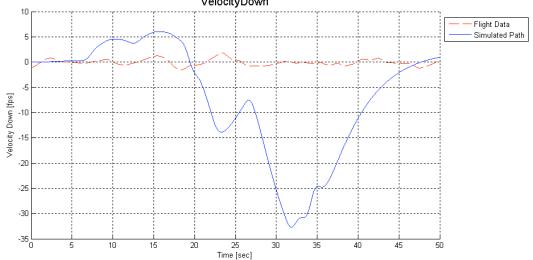
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 9 Waypoints



Proteus Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 9 Waypoints VelocityDown



Proteus Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing

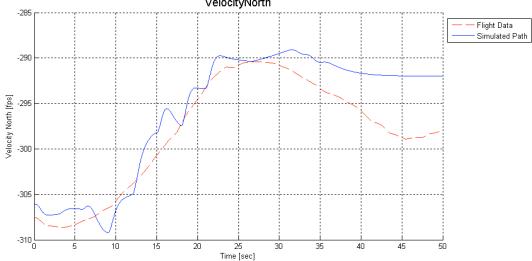
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 9 Waypoints

VelocityÉast -60 Flight Data Velocity East [fps] 15 20 50 Time [sec]

Proteus Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

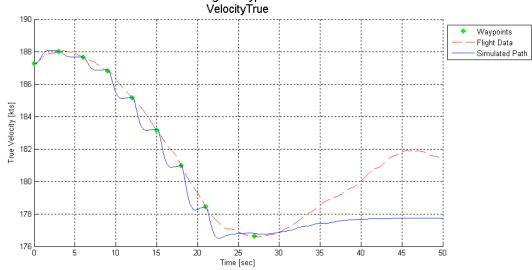
Using 9 Waypoints VelocityNorth



Proteus Time History Plot Flight No. 369 Run No. 2

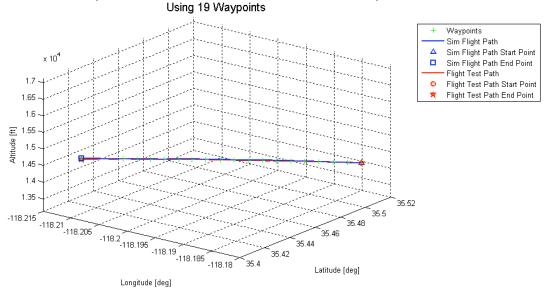
Scenario 3.03 Co-Heading, Intruder Climbing

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 9 Waypoints



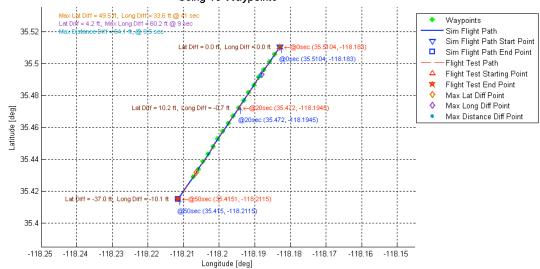
Generic G-III 3-D Plot Flight No. 369 Run No. 2 Scenario 3.03 Co-Heading, Intruder Climbing

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Inhibit: 2500; Sensor Advisory: TRT



Generic G-III Flight Path Position Plot Flight No. 369 Run No. 2 Scenario 3.03 Co-Heading, Intruder Climbing

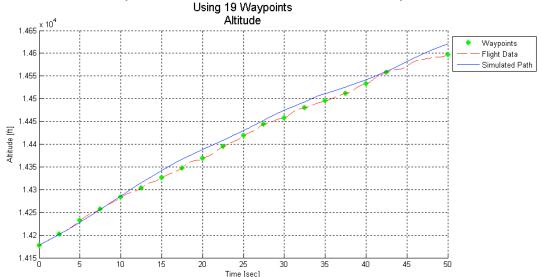
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 19 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 2

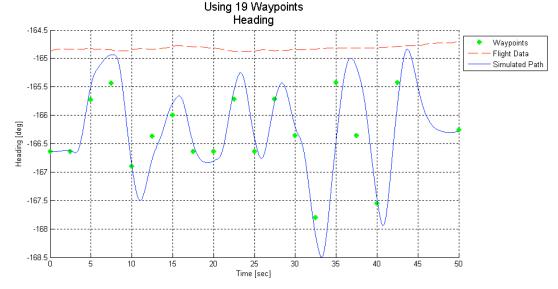
Scenario 3.03 Co-Heading, Intruder Climbing

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Generic G-III Time History Plot Flight No. 369 Run No. 2 Scenario 3.03 Co-Heading, Intruder Climbing

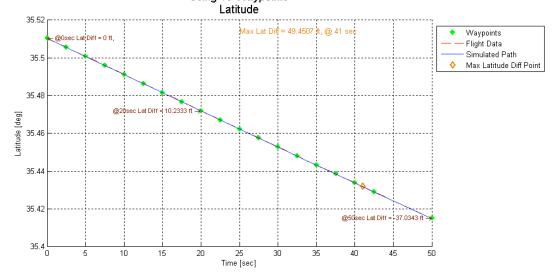
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Generic G-III Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing

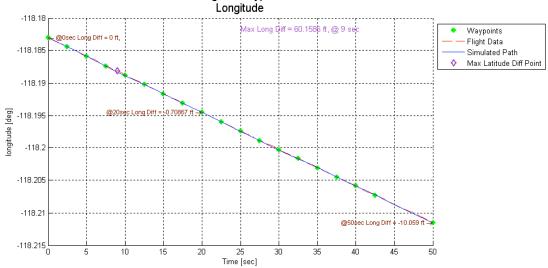
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 19 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

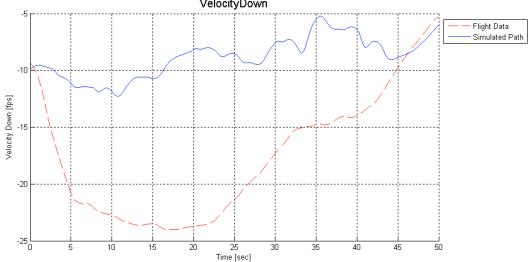
Using 19 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 2

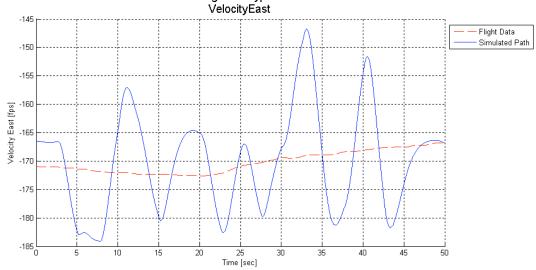
Scenario 3.03 Co-Heading, Intruder Climbing Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 19 Waypoints VelocityDown



Generic G-III Time History Plot Flight No. 369 Run No. 2

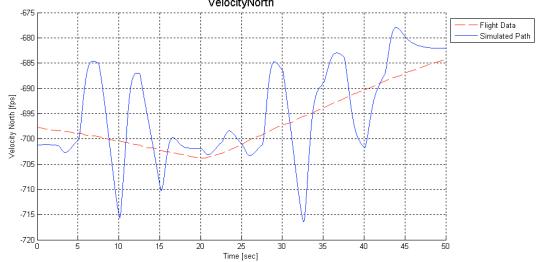
Scenario 3.03 Co-Heading, Intruder Climbing
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT
Using 19 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 19 Waypoints VelocityNorth



Generic G-III Time History Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Waypoints Flight Data Simulated Path

Using 19 Waypoints VelocityTrue 44∩ True Velocity [kts] 420

Time [sec]

30

35

40

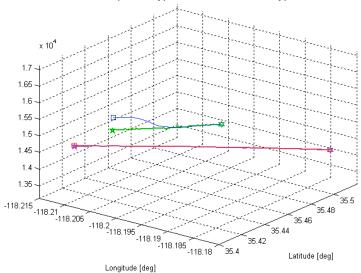
15

20

Proteus-Generic G-III 3-D Plot Flight No. 369 Run No. 2

Scenario 3.03 Co-Heading, Intruder Climbing

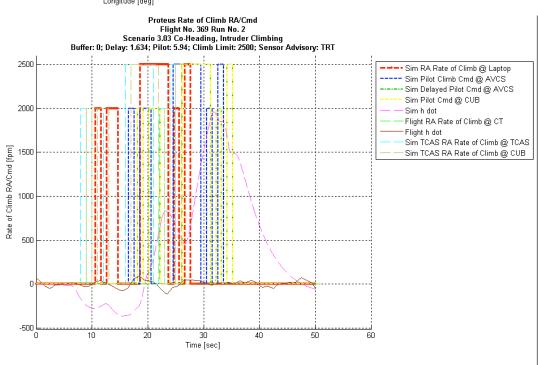
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Ownship: 9 Waypoints; Intruder: 19 Waypoints

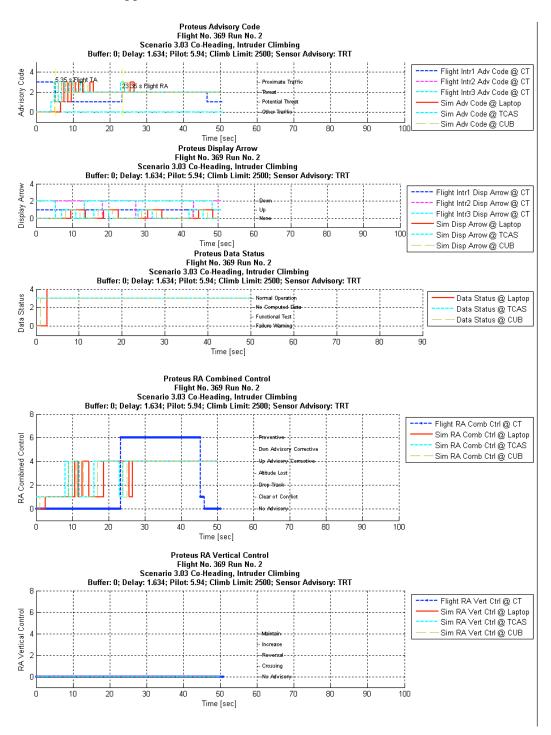


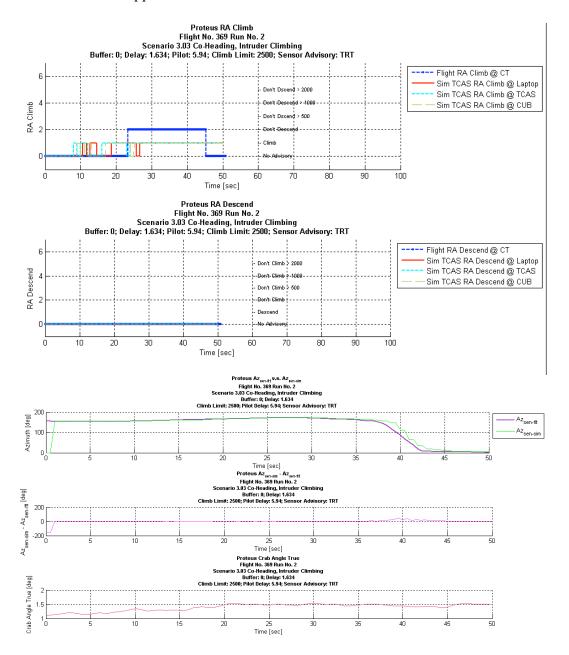


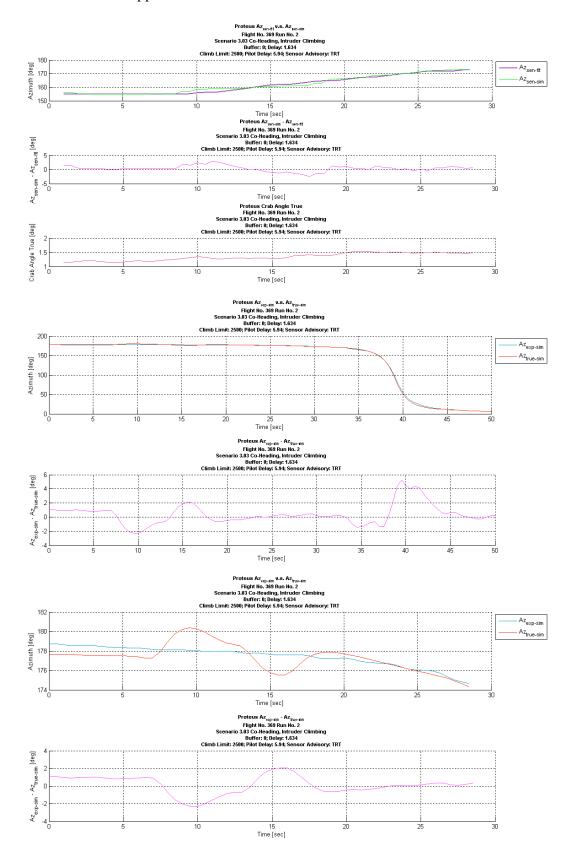
- Intruder Sim Flight Path

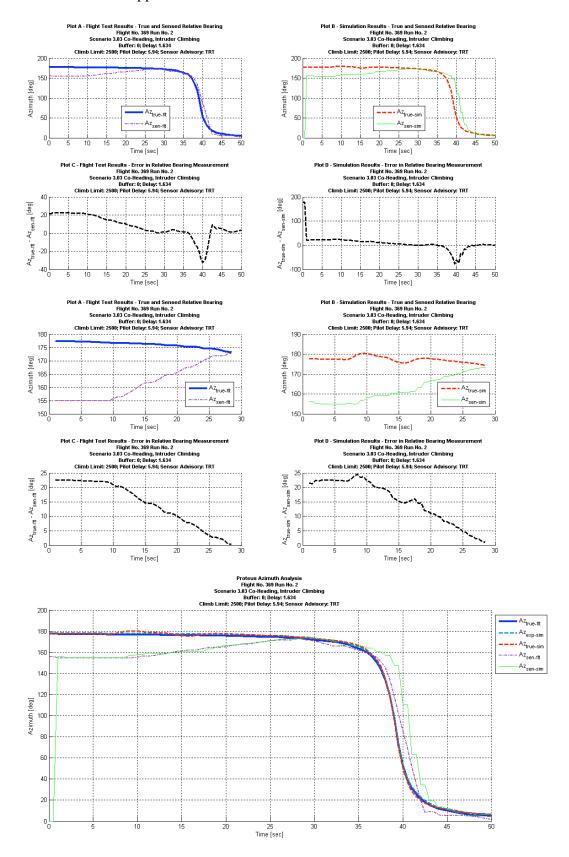
 ✓ Intruder Sim Flight Path Start Point
- Intruder Sim Flight Path End Point
 Ownship Flight Path
- △ Ownship Flight Path Start Point
 ★ Ownship Flight Path End Point
- ---- Intruder Flight Path
- △ Intruder Flight Path Start Point
- 🛪 Intruder Flight Path End Point

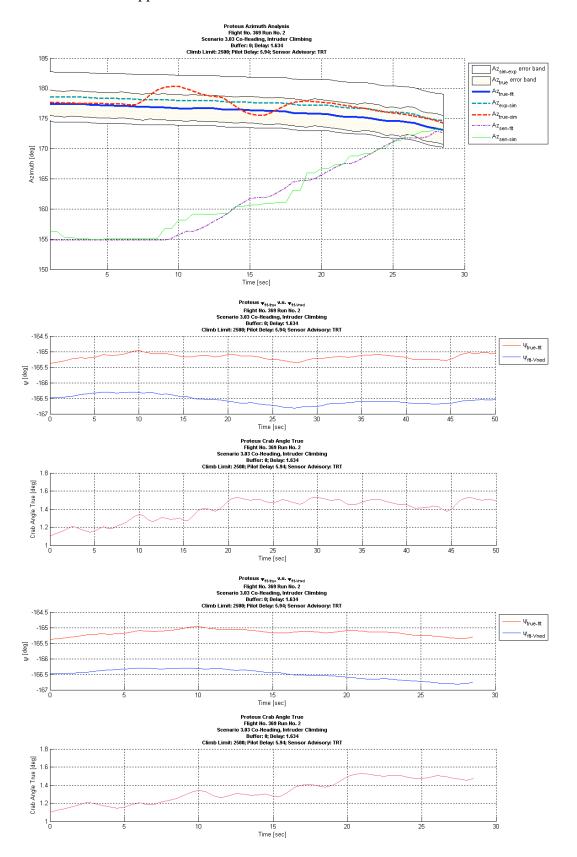


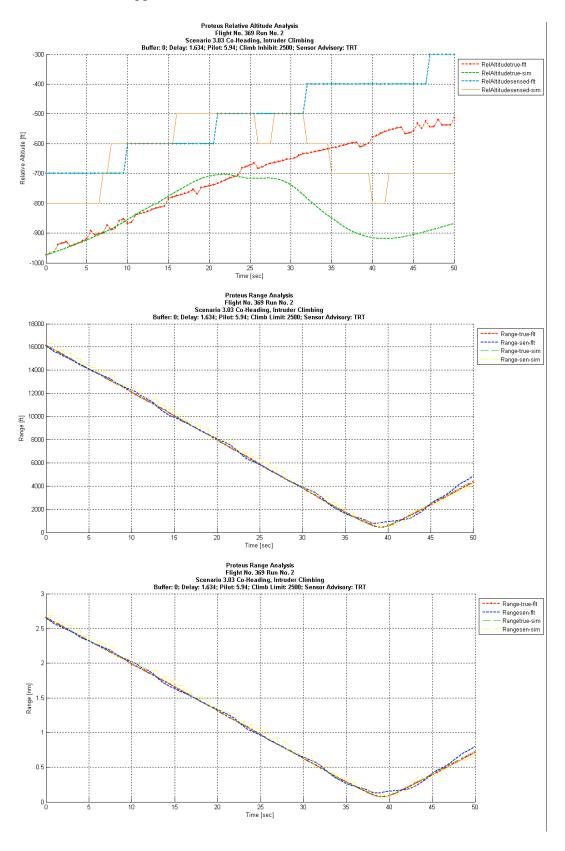






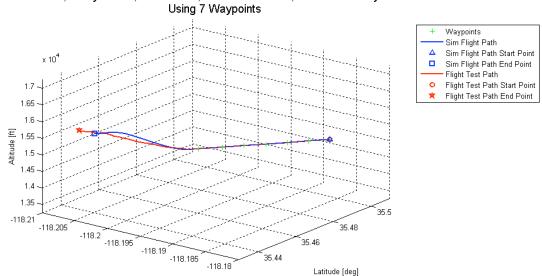






Flight 369 Run 6

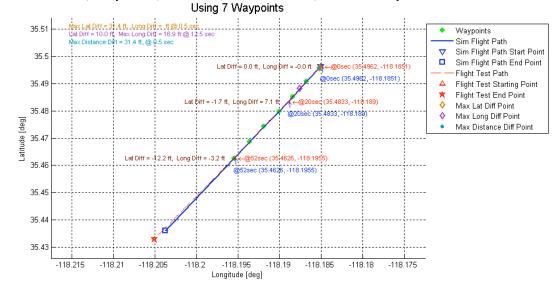
Proteus 3-D Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA



Proteus Flight Path Position Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

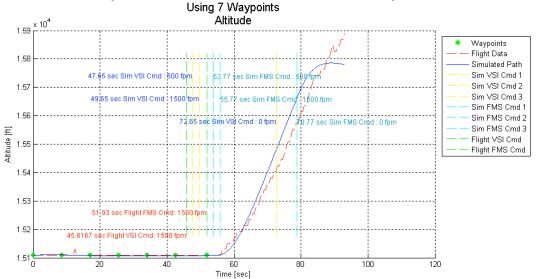
Longitude [deg]

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA



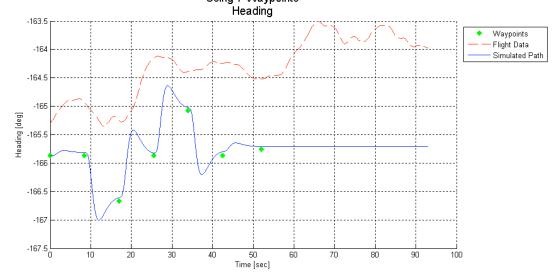
Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA



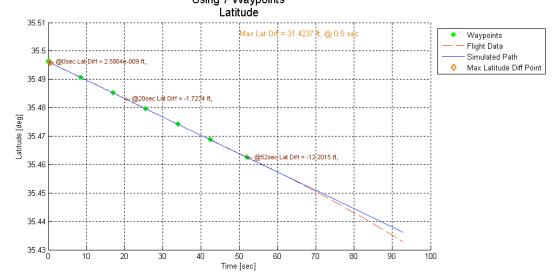
Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 7 Waypoints



Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 7 Waypoints



Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 7 Waypoints

Longitude -118.18 Max Long Diff = 16.8765 ft, @ 12.5 sec Waypoints Flight Data Simulated Path -118.185 Max Latitude Diff Point longitude [deg] -118.2 -118.205 -118.21 L 20 30 40 50 70 80 90 100 Time [sec]

Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA
Using 7 Waypoints
VelocityDown

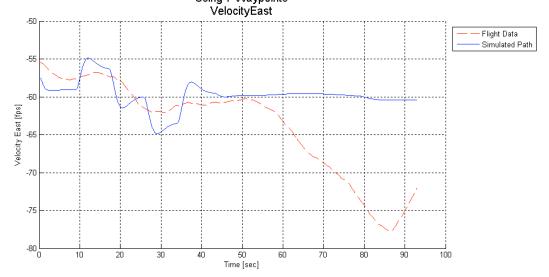
VelocityDown

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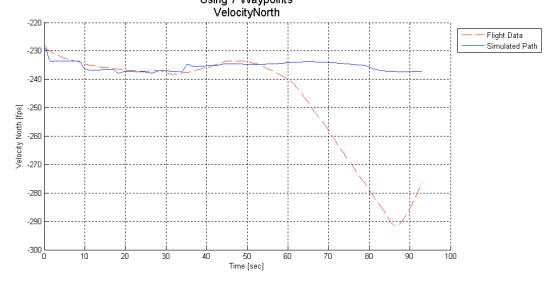
Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 7 Waypoints



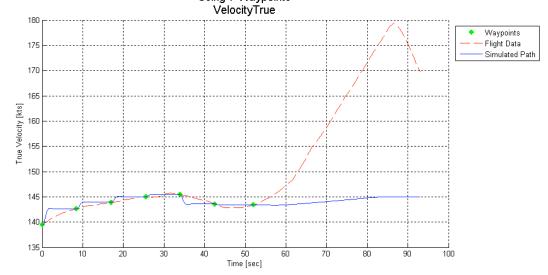
Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 7 Waypoints



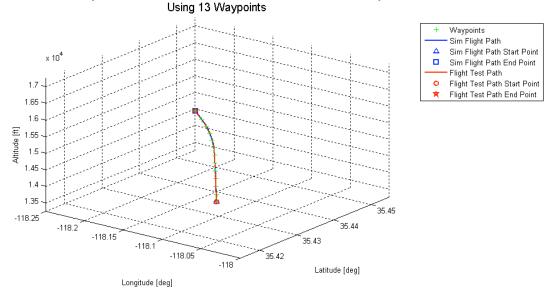
Proteus Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 7 Waypoints



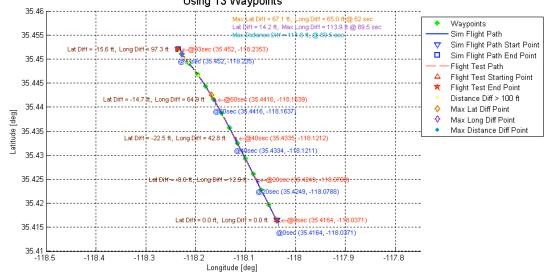
Generic G-III 3-D Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Inhibit: 2500; Sensor Advisory: AGA



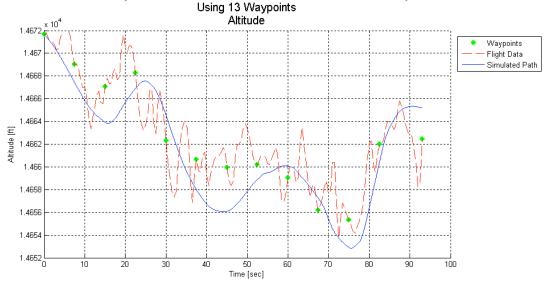
Generic G-III Flight Path Position Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 13 Waypoints



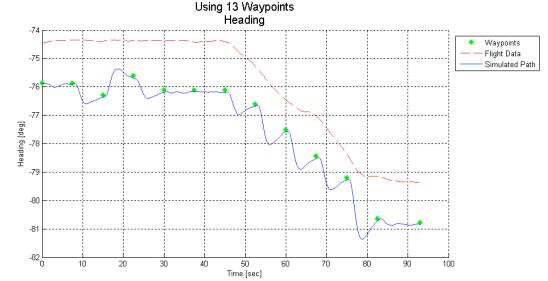
Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA



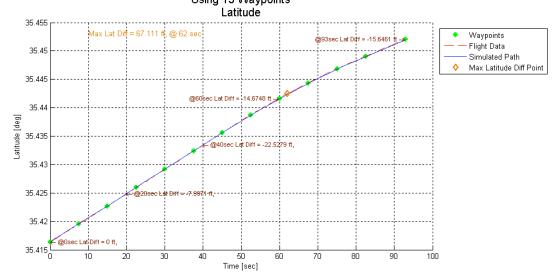
Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA



Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 13 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 13 Waypoints

Longitude Max Long Diff = 113.8707 ft, @ 89.5 sec Waypoints Flight Data Simulated Path Max Latitude Diff Point -118.05 longitude [deg] -118.15 -118.2 -118.25 L 20 30 40 50 70 80 90 100 Time [sec]

Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA

Using 13 Waypoints
VelocityDown

1.5

——Flight Data
——Simulated Path

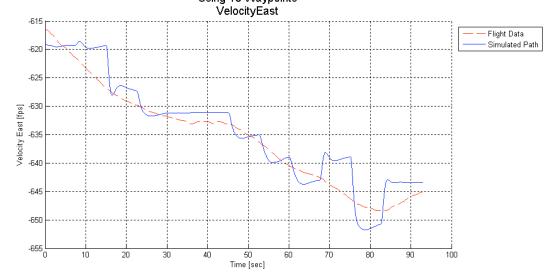
——Simulated Path

——Simulated Path

——Flight Data
——Fl

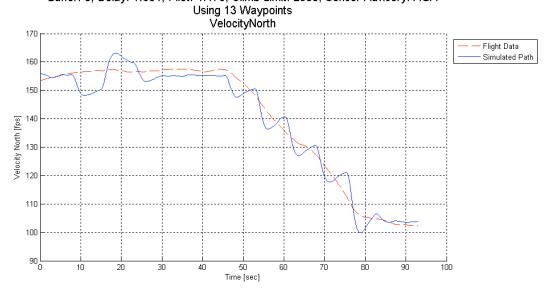
Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 13 Waypoints



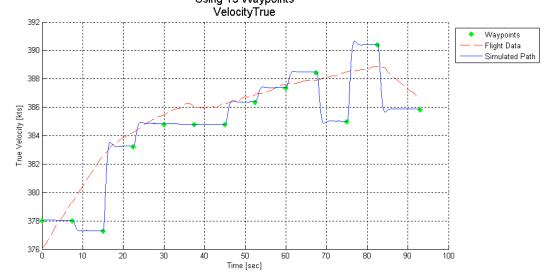
Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA



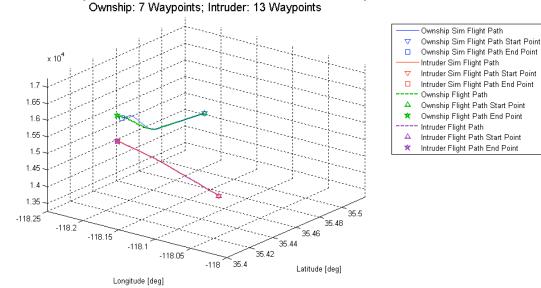
Generic G-III Time History Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

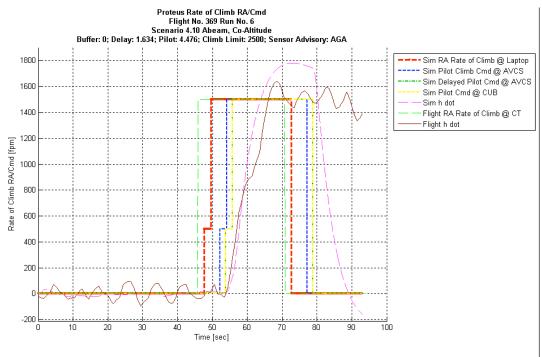
Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA Using 13 Waypoints

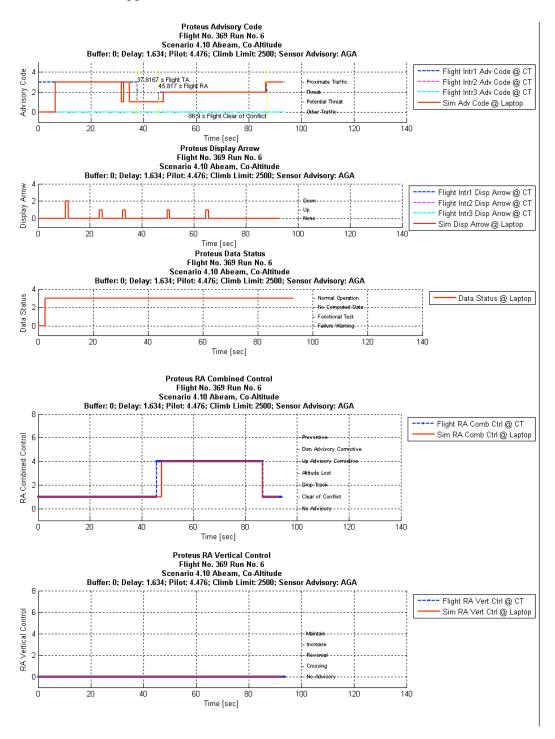


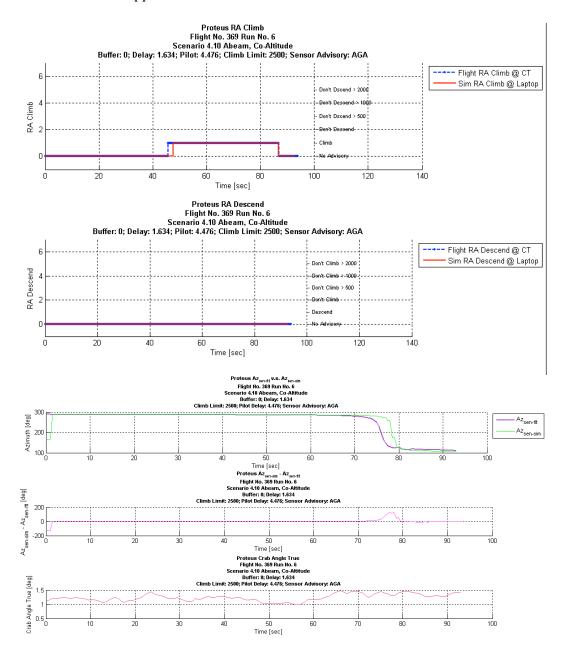
Proteus-Generic G-III 3-D Plot Flight No. 369 Run No. 6 Scenario 4.10 Abeam, Co-Altitude

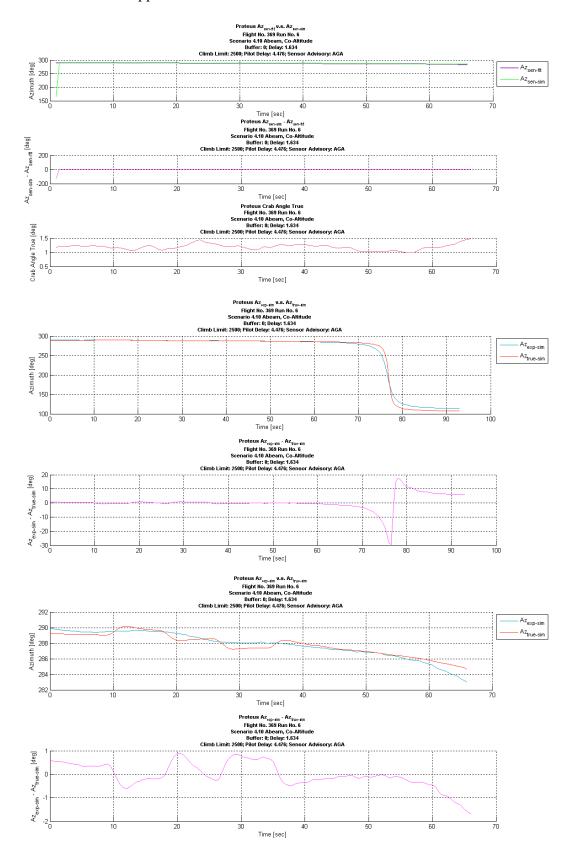
Buffer: 0; Delay: 1.634; Pilot: 4.476; Climb Limit: 2500; Sensor Advisory: AGA

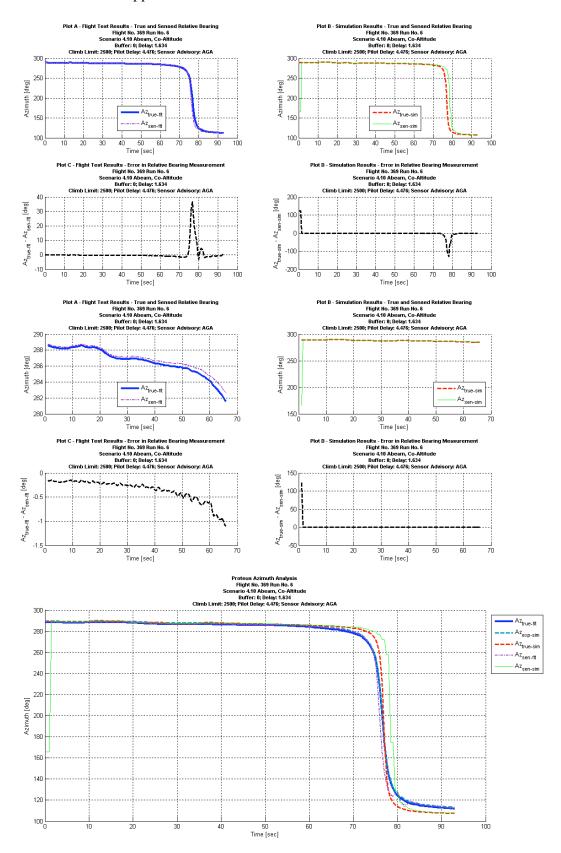


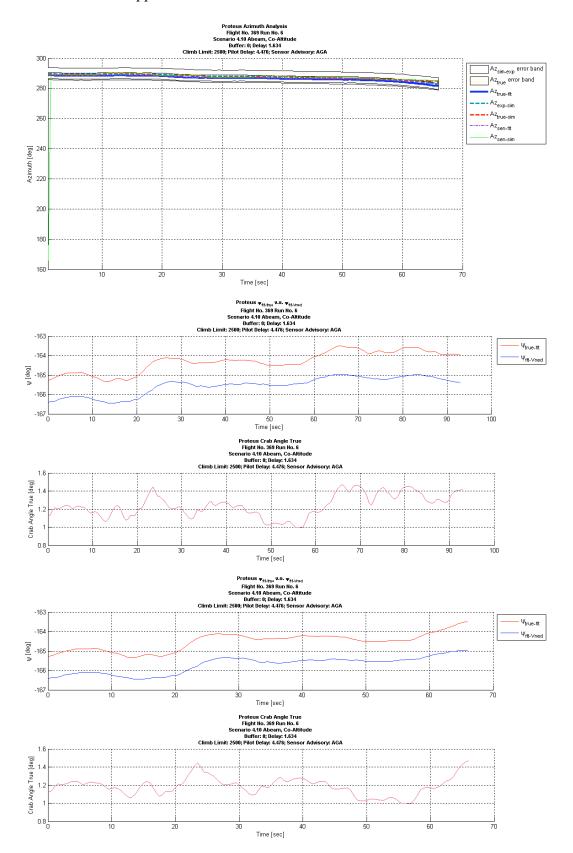


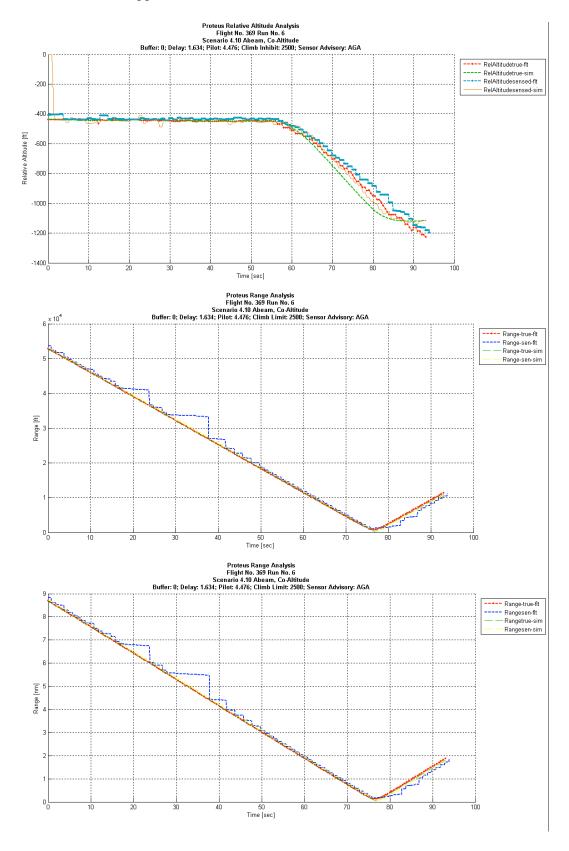












Flight 369 Run 7

Proteus 3-D Plot Flight No. 369 Run No. 7

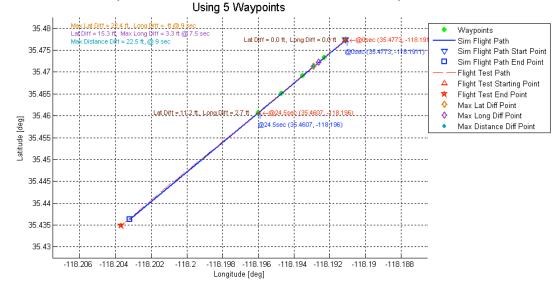
Scenario 5.09 Head-On, Co-Altitude Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA

Using 5 Waypoints Waypoints Sim Flight Path Sim Flight Path Start Point Sim Flight Path End Point Flight Test Path Flight Test Path Start Point 1.7 Flight Test Path End Point 1.65 Altitude [ft] 35.47 -118.2 -118.198 -118.196 -118.194 -118.192 35.45 -118.19 35.43 Latitude [deg]

Proteus Flight Path Position Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

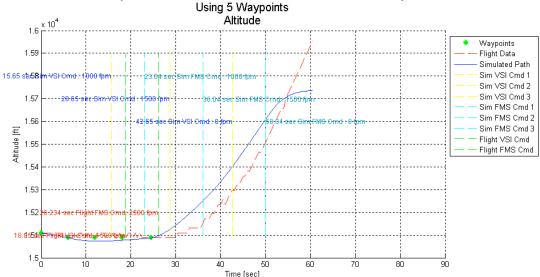
Longitude [deg]

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA

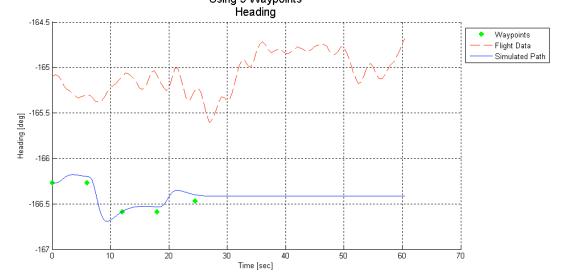


Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA

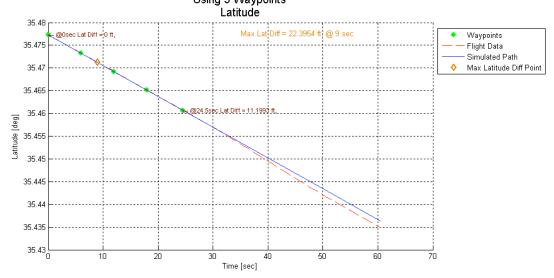


Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

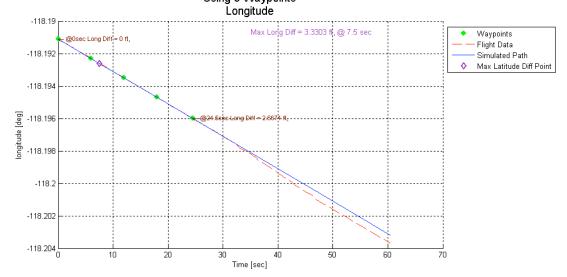


Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA Using 5 Waypoints



Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude



Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

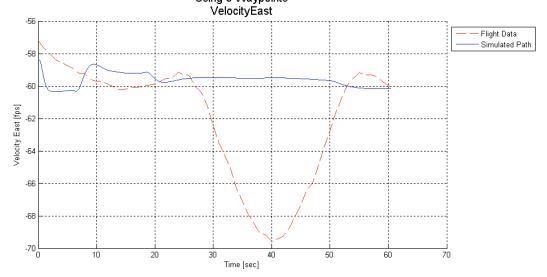
Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA Using 5 Waypoints

VelocityDown

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Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude



Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA Using 5 Waypoints

VelocityNorth

-240

-245

-250

-265

-270

-275

-280

10

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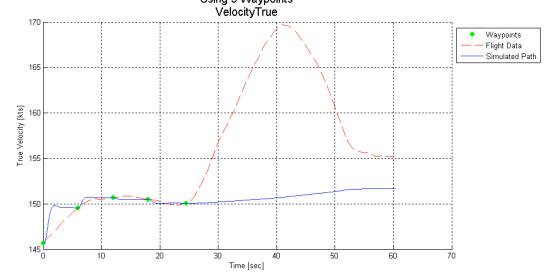
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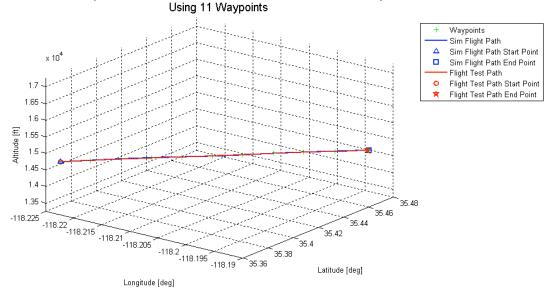
Time [sec]

Proteus Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

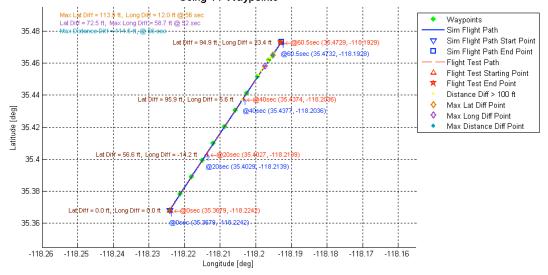


Generic G-III 3-D Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Inhibit: 2500; Sensor Advisory: AGA

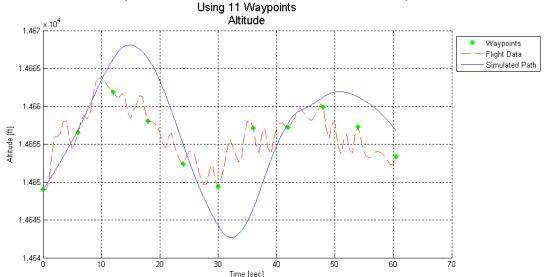


Generic G-III Flight Path Position Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

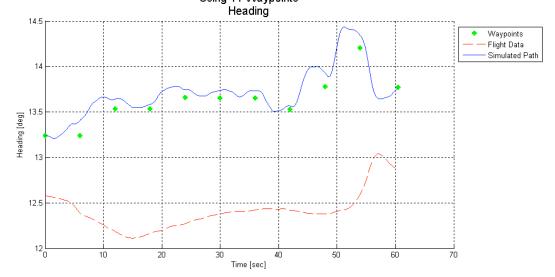


Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA

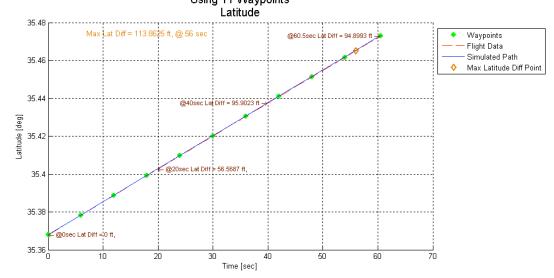


Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

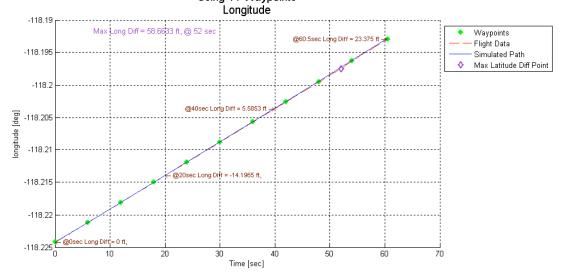


Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA Using 11 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude



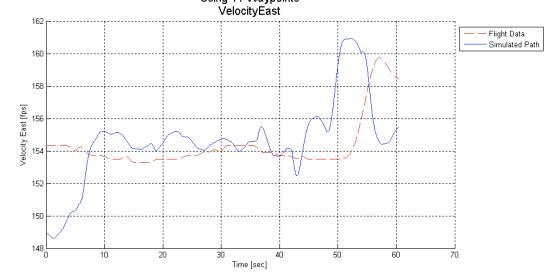
Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA

Using 11 Waypoints
VelocityDown

—— Flight Data
—— Simulated Path

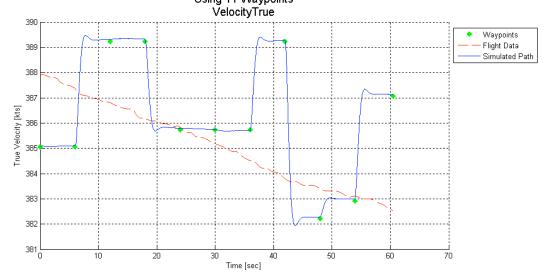
Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude



Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

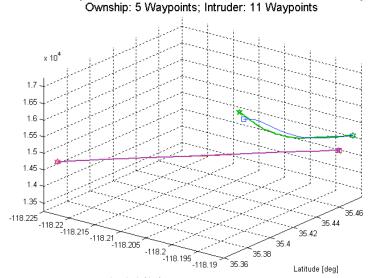
Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA Using 11 Waypoints

> Generic G-III Time History Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude



Proteus-Generic G-III 3-D Plot Flight No. 369 Run No. 7 Scenario 5.09 Head-On, Co-Altitude

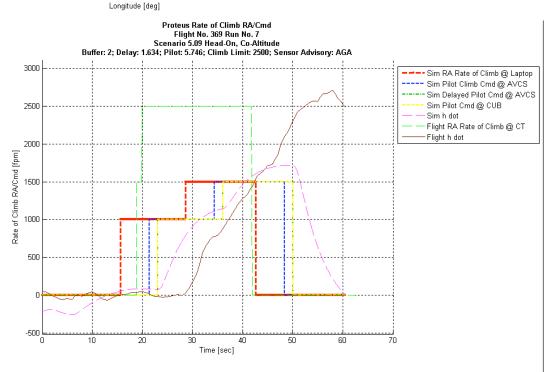
Buffer: 2; Delay: 1.634; Pilot: 5.746; Climb Limit: 2500; Sensor Advisory: AGA

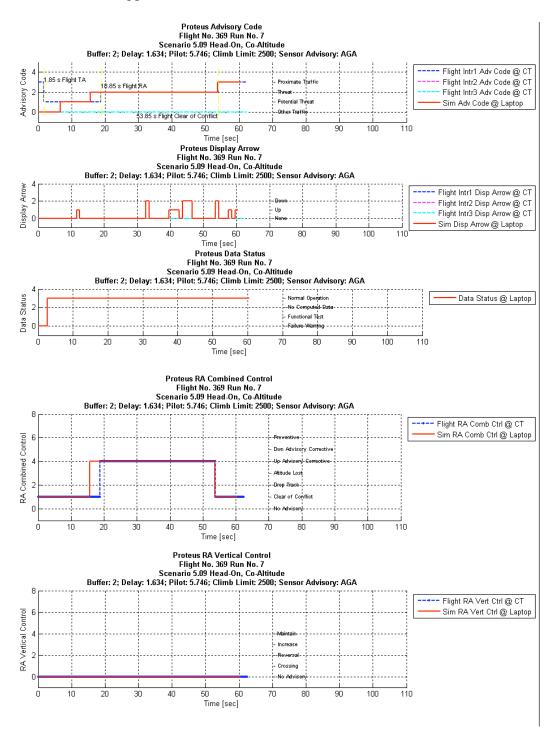


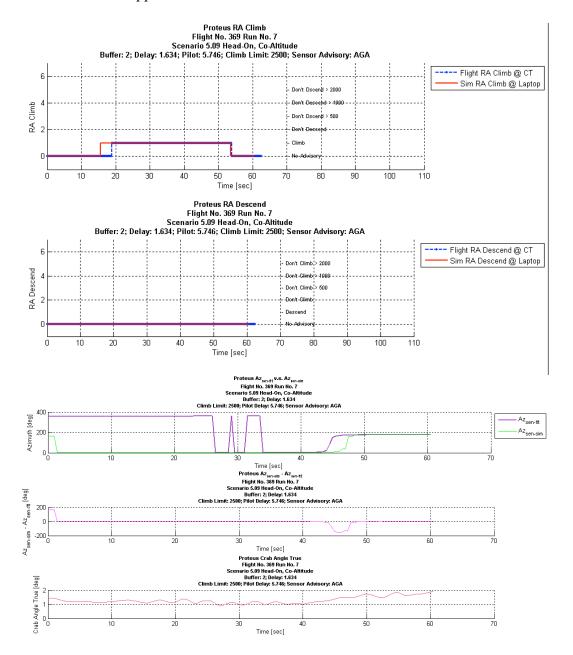
○ Ownship Sim Flight Path Start Point
 ○ Ownship Sim Flight Path End Point
 ○ Intruder Sim Flight Path
 ○ Intruder Sim Flight Path Start Point
 ○ Intruder Sim Flight Path End Point
 ○ Ownship Flight Path
 △ Ownship Flight Path Start Point
 ◆ Ownship Flight Path End Point
 ○ Intruder Flight Path
 △ Intruder Flight Path

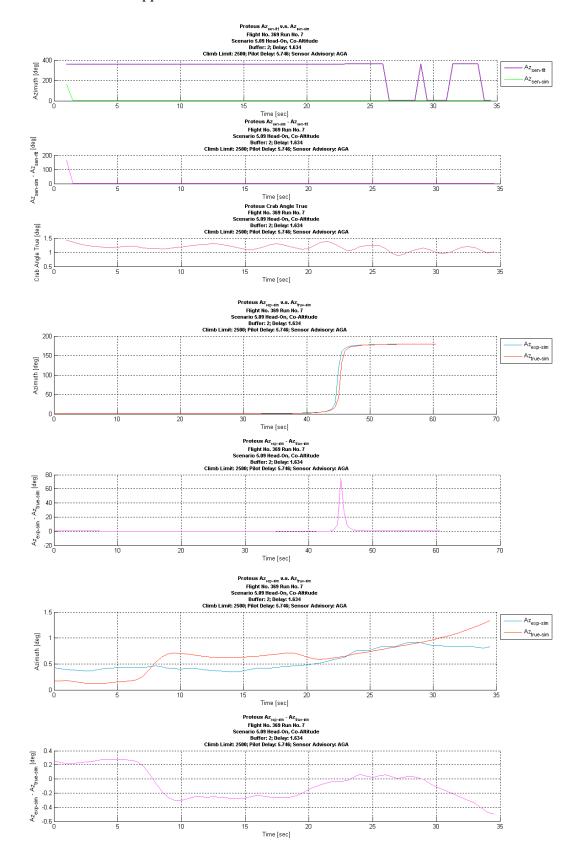
Intruder Flight Path End Point

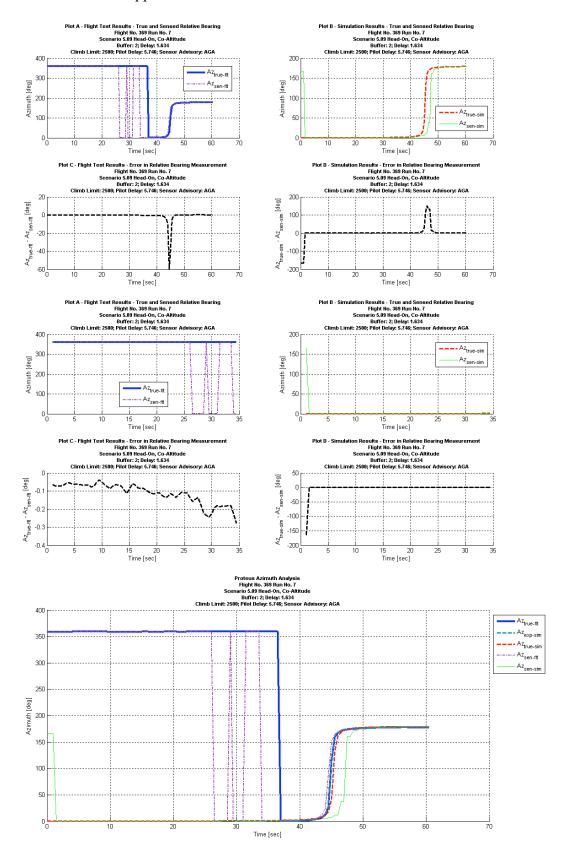
Ownship Sim Flight Path

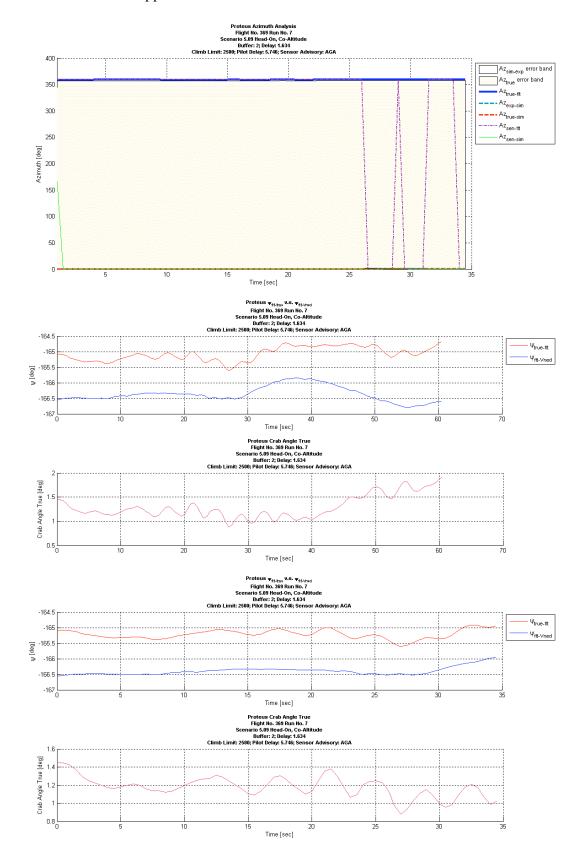


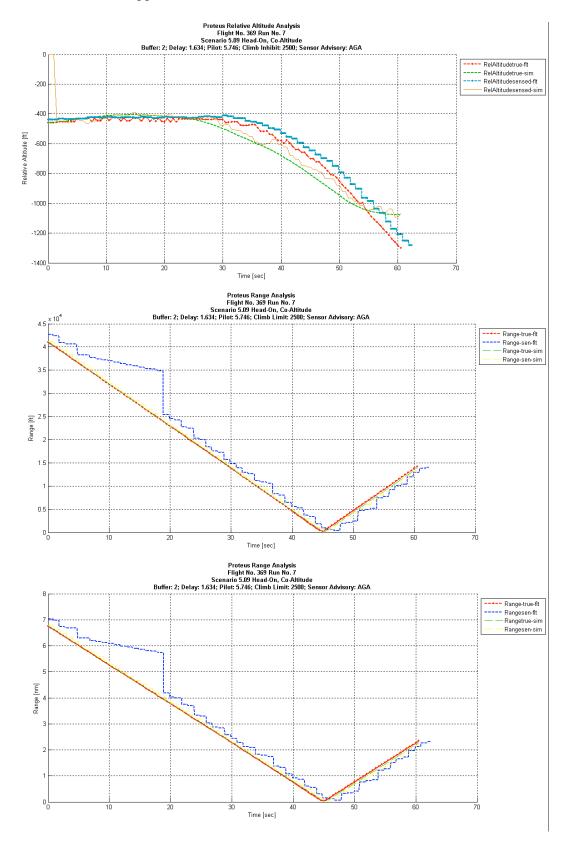








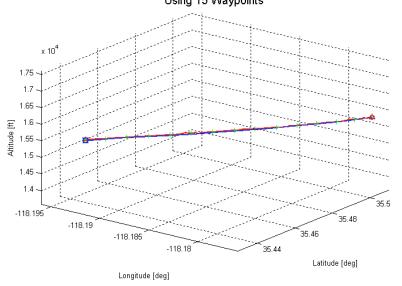




Flight 369 Run 13

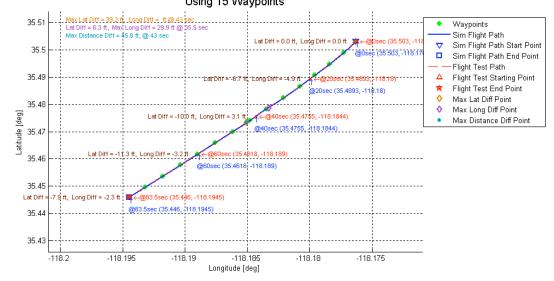
Proteus 3-D Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 15 Waypoints



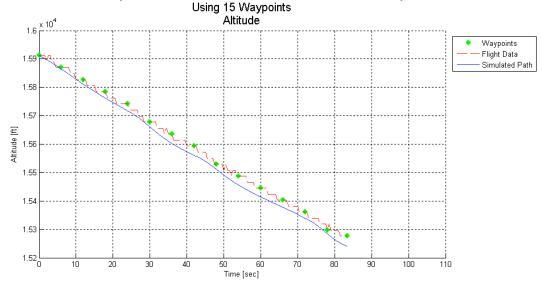
+ Waypoints
Sim Flight Path
△ Sim Flight Path Start Point
□ Sim Flight Path End Point
Flight Test Path
○ Flight Test Path Start Point
★ Flight Test Path End Point

Proteus Flight Path Position Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude



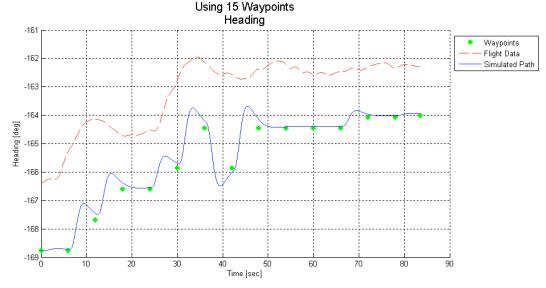
Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA



Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

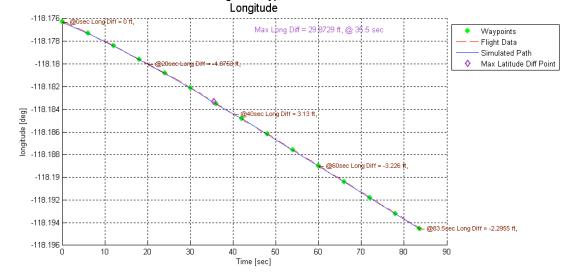


Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 15 Waypoints

| Solution | Color |

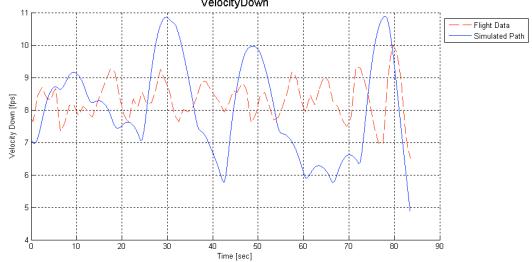
Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude



Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

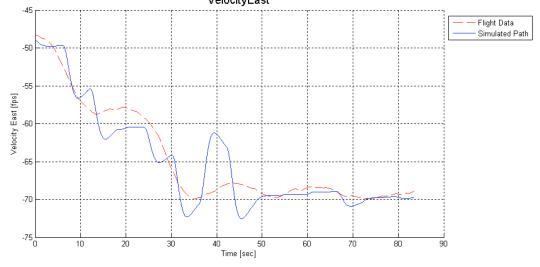
Using 15 Waypoints VelocityDown



Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

Using 15 Waypoints VelocityEast



Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

Using 15 Waypoints
VelocityNorth

-242

-244

-246

-246

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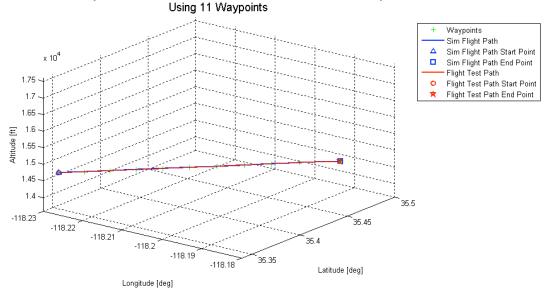
Proteus Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 15 Waypoints

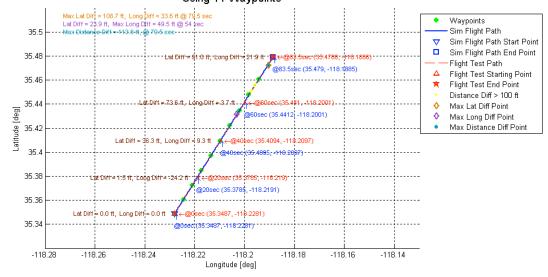
VelocityTrue 155 Waypoints Flight Data Simulated Path True Velocity [kts] 151 150 40 Time [sec] 10 20 30 60 70 80 90

Generic G-III 3-D Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Inhibit: 2500; Sensor Advisory: AGA

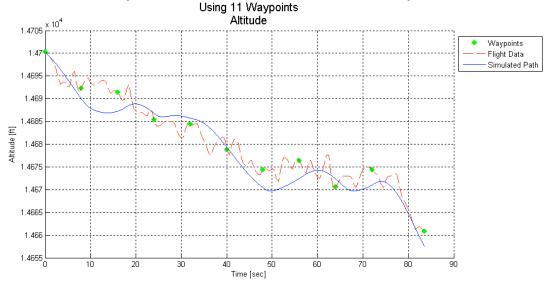


Generic G-III Flight Path Position Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude



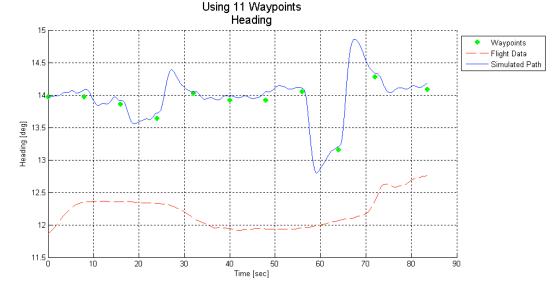
Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA



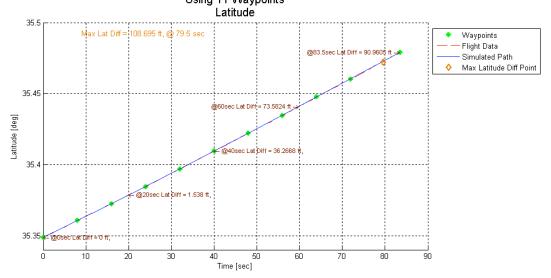
Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

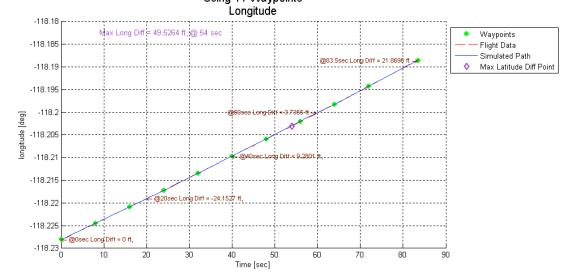


Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 11 Waypoints



Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude



Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

> Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 11 Waypoints

VelocityEast

150

Flight Data
Simulated Path

150

130

130

130

10

20

30

40

50

Time [sec]

Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 11 Waypoints

VelocityNorth Flight Data Simulated Path Velocity North [fps] 550 540 520 L 50

> Generic G-III Time History Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA Using 11 Waypoints

VelocityTrue 360 Waypoints Flight Data 355 Simulated Path 350 True Velocity [kts] 330 325 320 L

70

40 Time [sec]

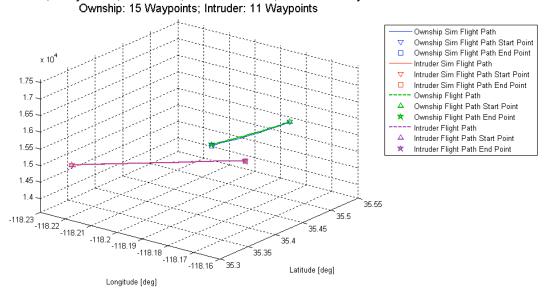
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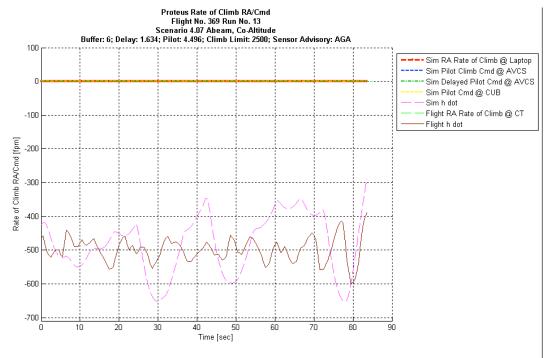
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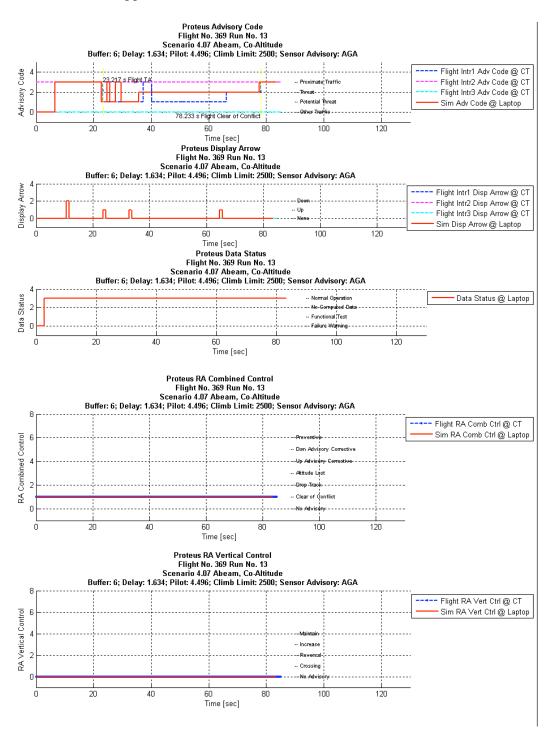
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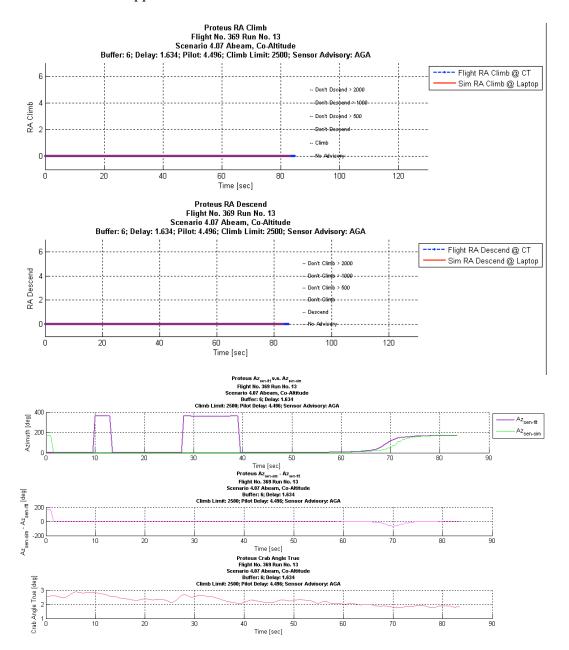
Proteus-Generic G-III 3-D Plot Flight No. 369 Run No. 13 Scenario 4.07 Abeam, Co-Altitude

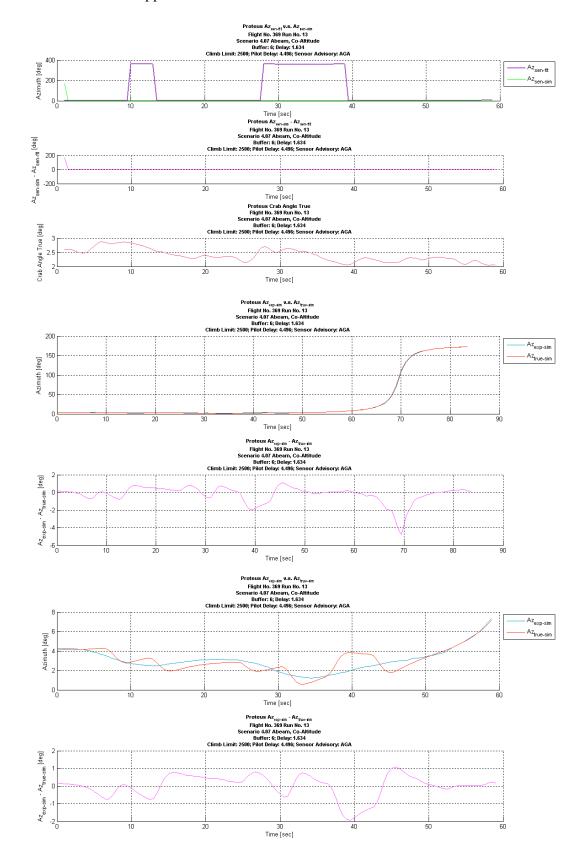
Buffer: 6; Delay: 1.634; Pilot: 4.496; Climb Limit: 2500; Sensor Advisory: AGA

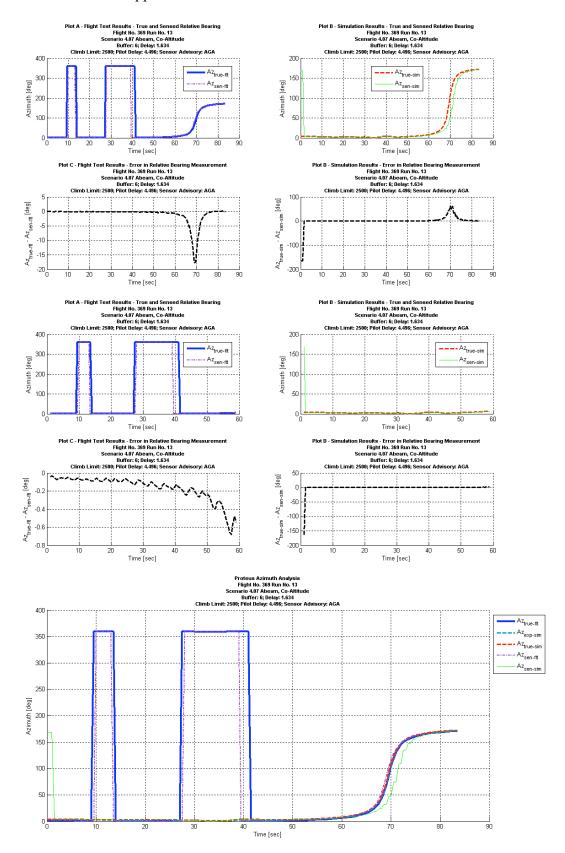


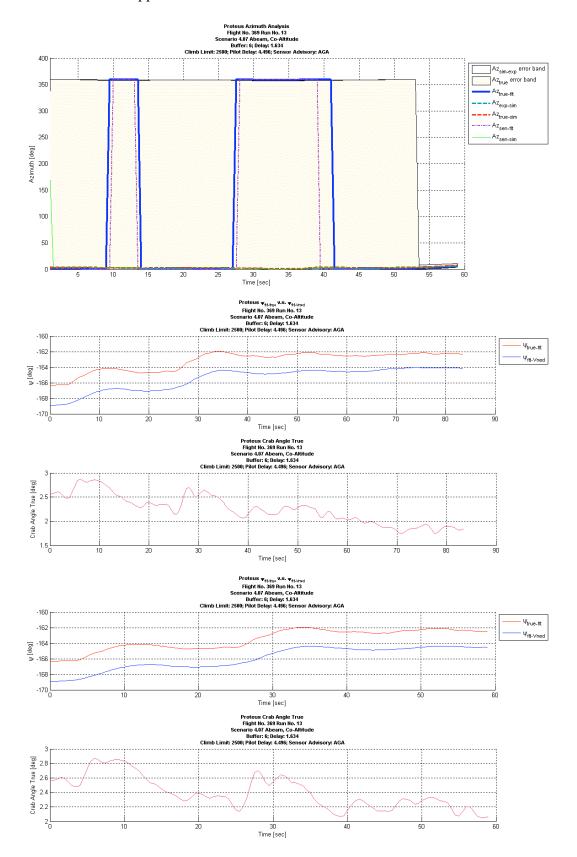


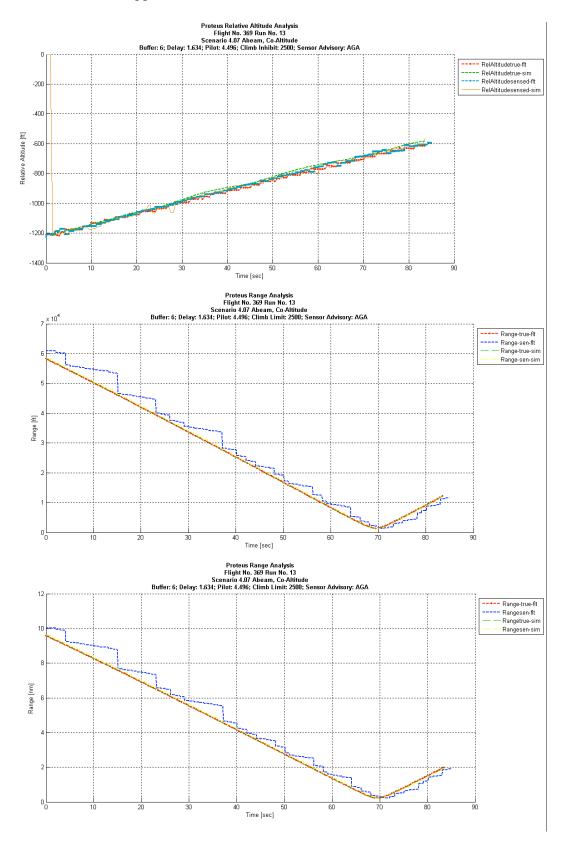






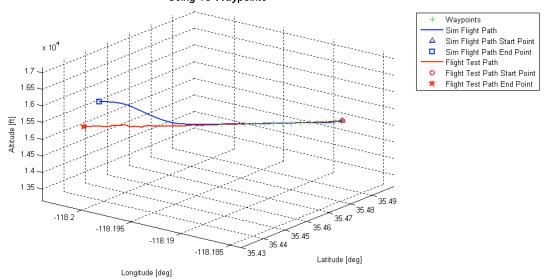






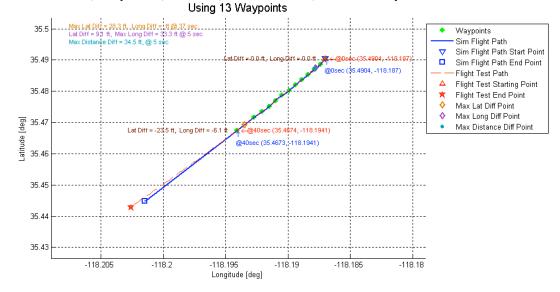
Flight 370 Run 2

Proteus 3-D Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints



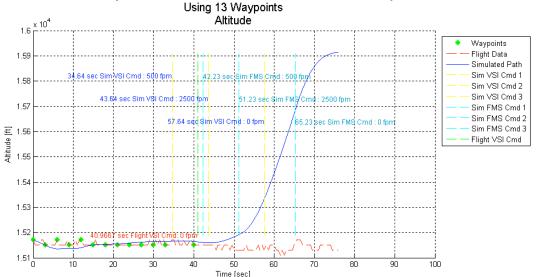
Proteus Flight Path Position Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



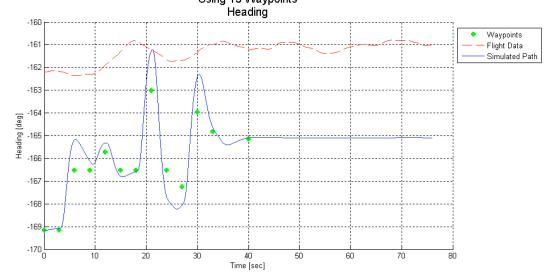
Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



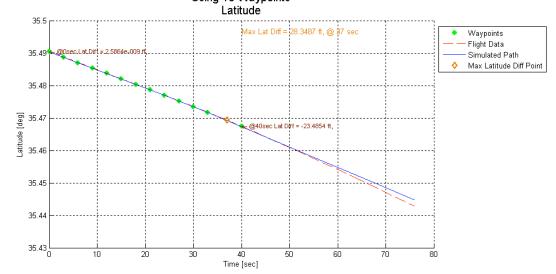
Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints



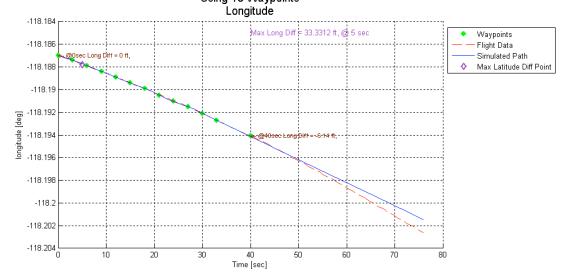
Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints



Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

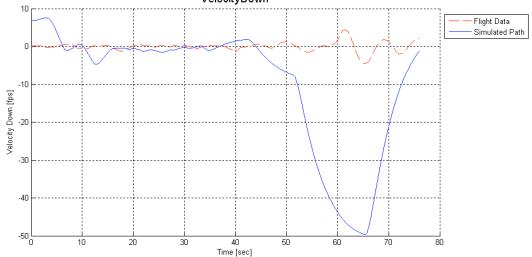
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints



Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

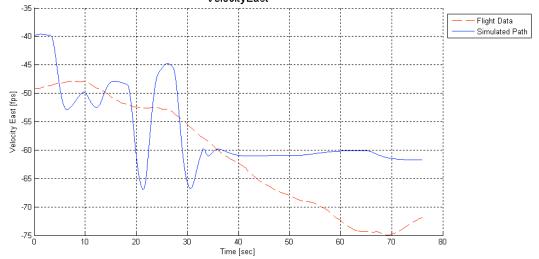
Using 13 Waypoints VelocityDown



Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints

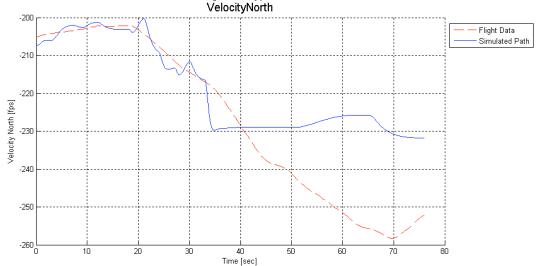
VelocityEast



Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 13 Waypoints



Proteus Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints

150

120 L

10

20

30

40

Time [sec]

70

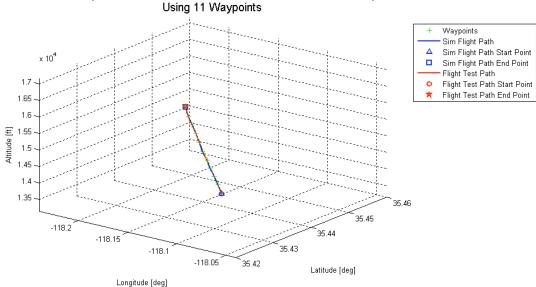
True Velocity [kts]

VelocityTrue

Waypoints
— Flight Data
— Simulated Path

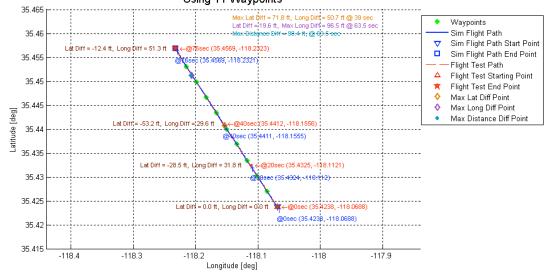
Generic G-III 3-D Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Inhibit: 2500; Sensor Advisory: TRT



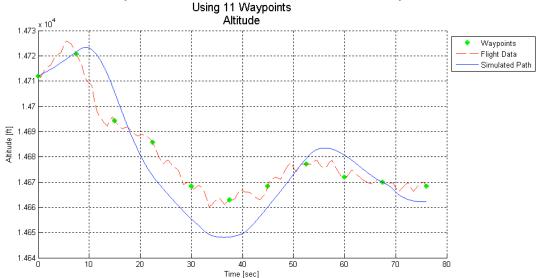
Generic G-III Flight Path Position Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints



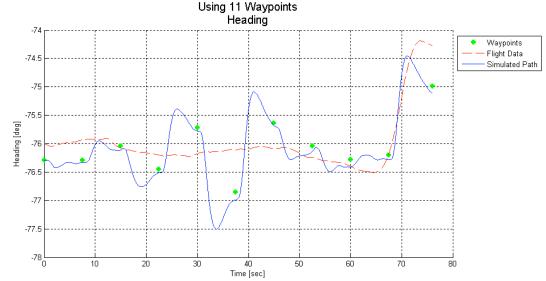
Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



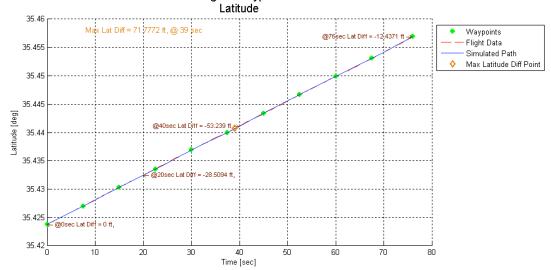
Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



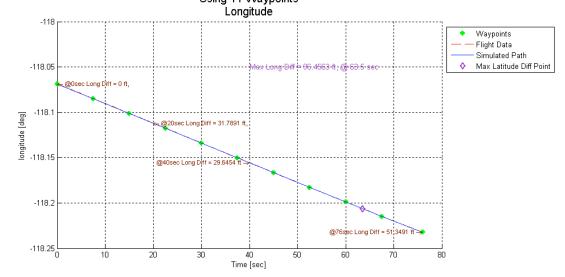
Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

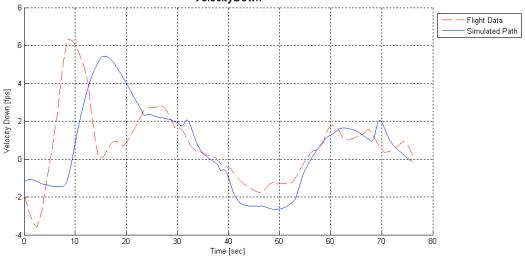
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Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

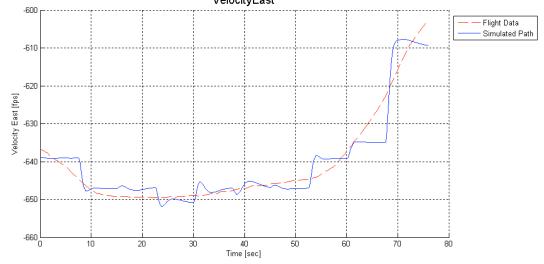
Using 11 Waypoints VelocityDown



Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints

VelocityEast



Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 11 Waypoints
VelocityNorth

Flight Data
Simulated Path

Generic G-III Time History Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

Time [sec]

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints

VelocityTrue

Waypoints
Flight Data
Simulated Path

380

370

10

20

30

40

50

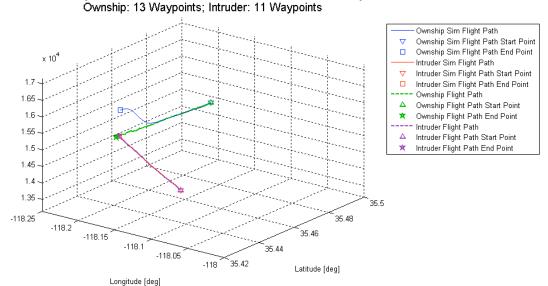
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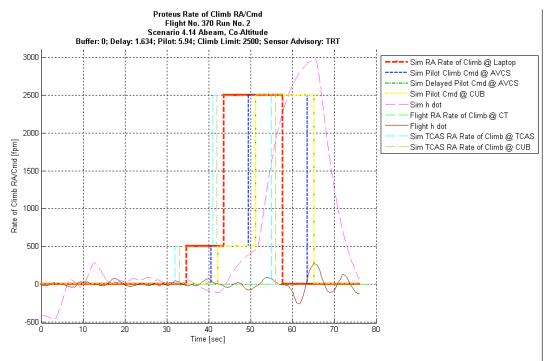
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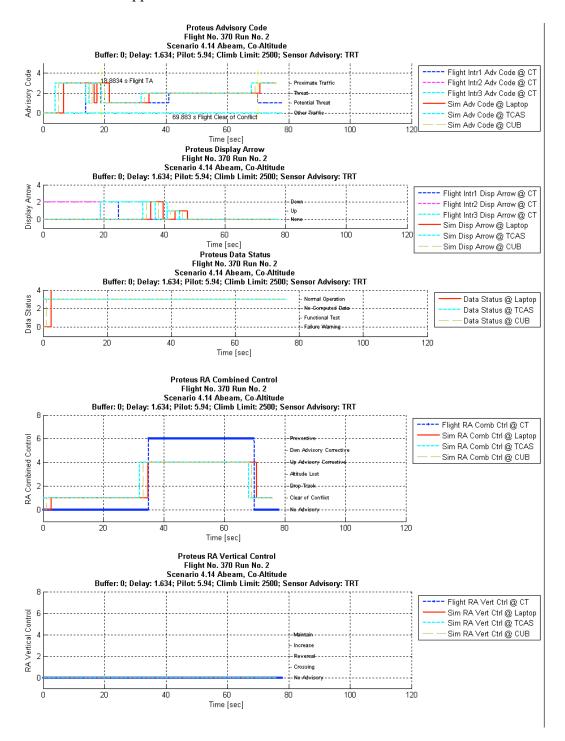
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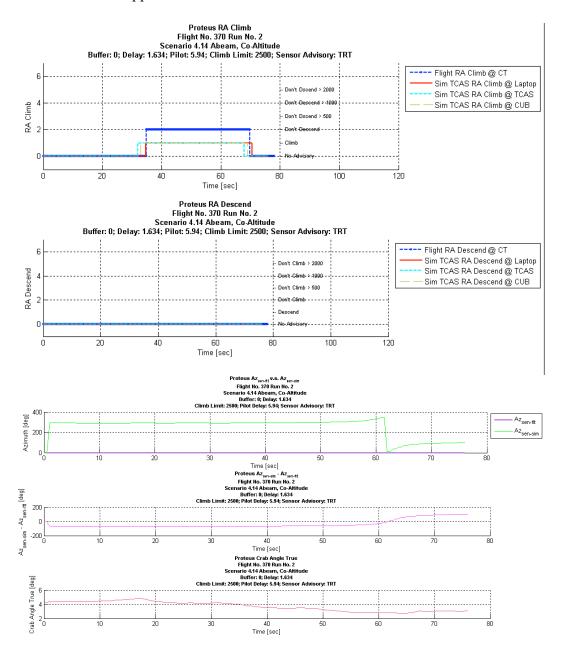
Proteus-Generic G-III 3-D Plot Flight No. 370 Run No. 2 Scenario 4.14 Abeam, Co-Altitude

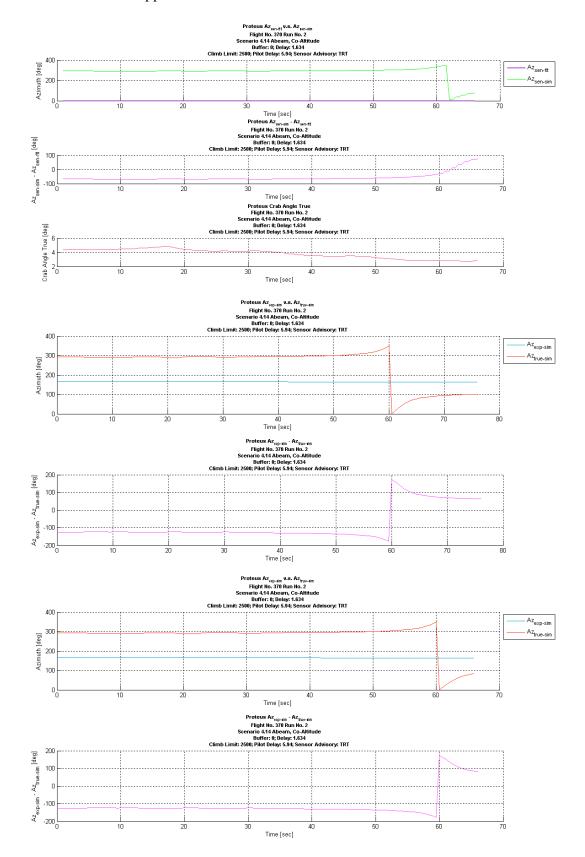
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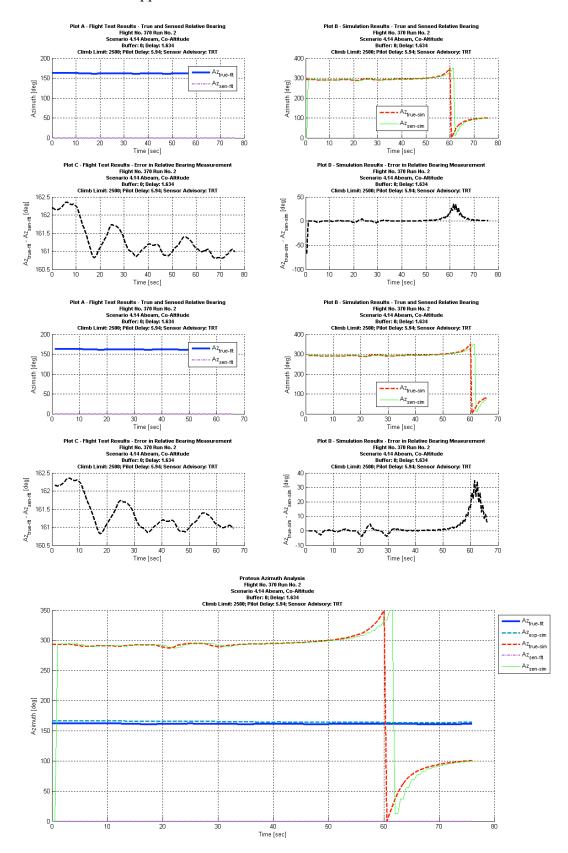


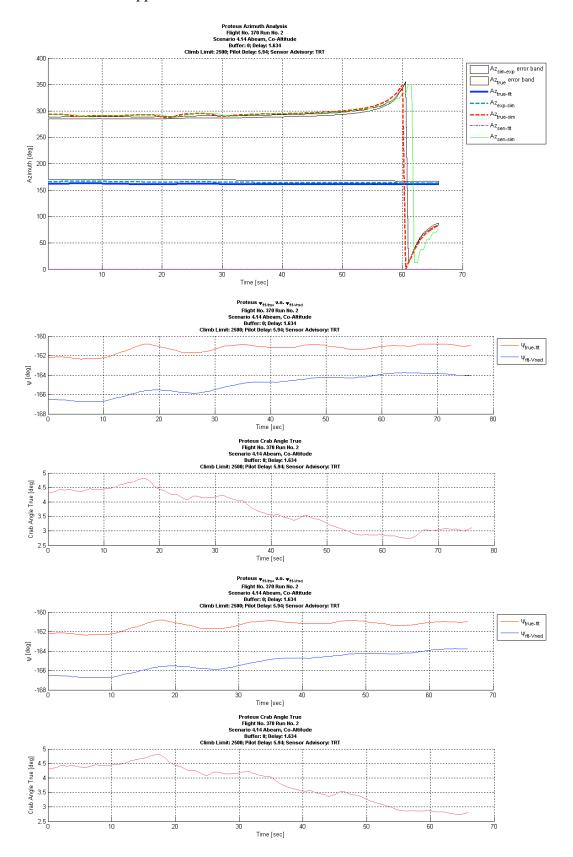


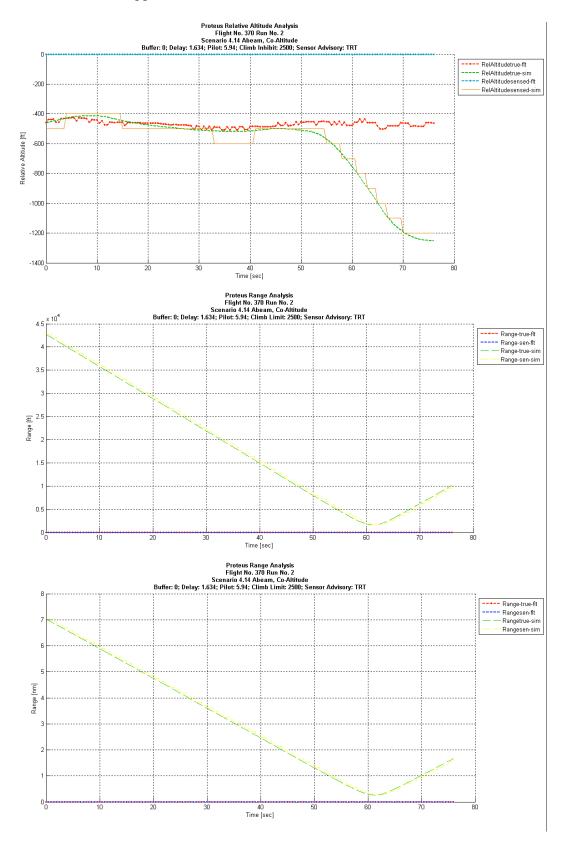








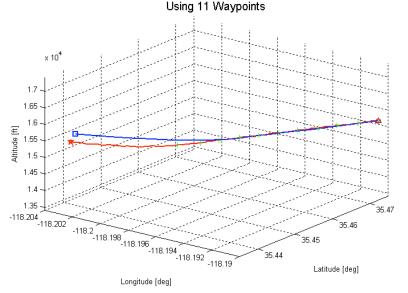




Flight 370 Run 6

Proteus 3-D Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

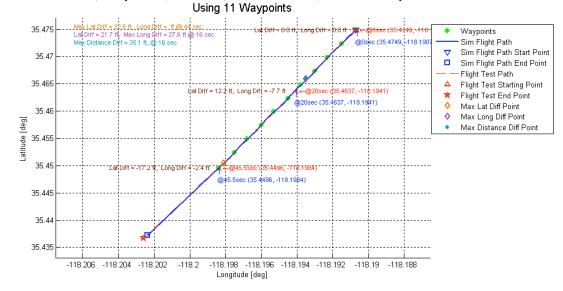
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



+ Waypoints
Sim Flight Path
△ Sim Flight Path Start Point
□ Sim Flight Path End Point
Flight Test Path
♥ Flight Test Path Start Point
▼ Flight Test Path End Point

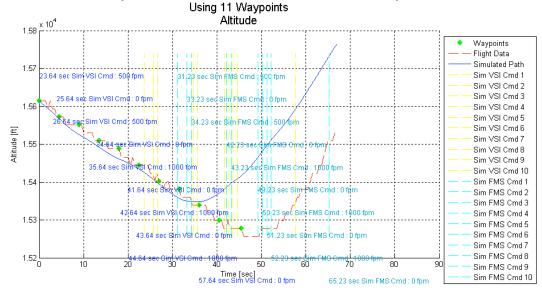
Proteus Flight Path Position Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



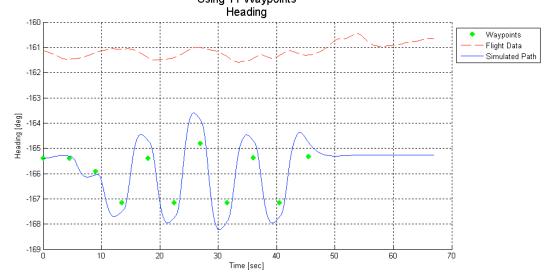
Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

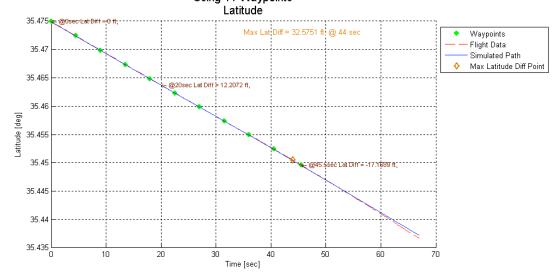
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints



Proteus Time History Plot Flight No. 370 Run No. 6

Scenario 6.13 Head-On, Host Descending

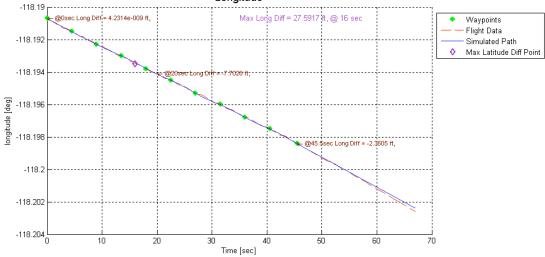
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Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

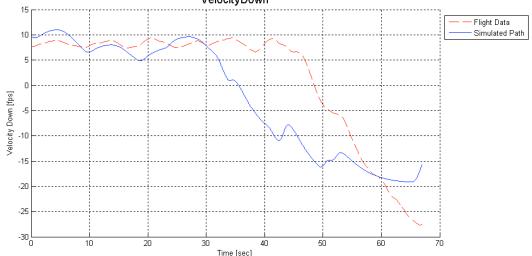
Using 11 Waypoints Longitude



Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

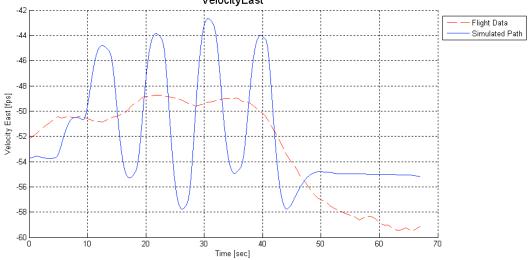
Using 11 Waypoints VelocityDown



Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

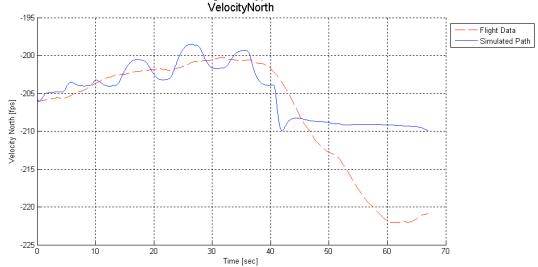
Using 11 Waypoints VelocityEast



Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

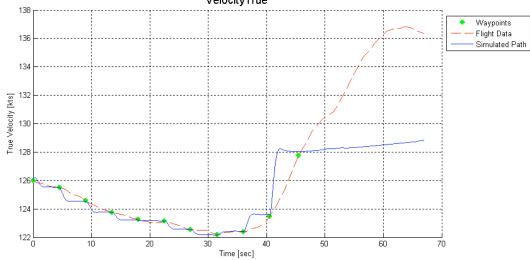
Using 11 Waypoints



Proteus Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

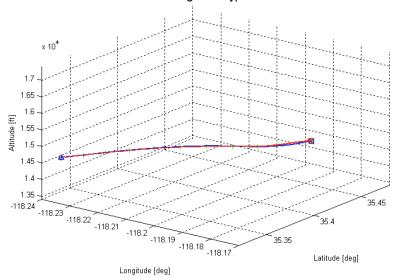
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 11 Waypoints VelocityTrue



Generic G-III 3-D Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

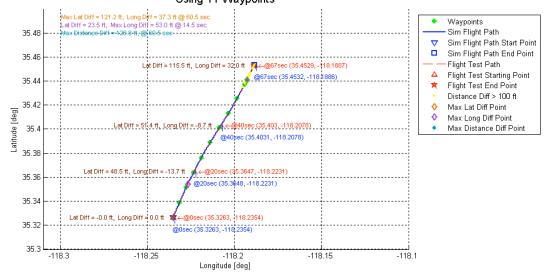
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Inhibit: 2500; Sensor Advisory: TRT Using 11 Waypoints



+ Waypoints
Sim Flight Path
△ Sim Flight Path Start Point
□ Sim Flight Path End Point
Flight Test Path
○ Flight Test Path Start Point
★ Flight Test Path End Point

Generic G-III Flight Path Position Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 11 Waypoints
Altitude

1.472

1.468

1.464

1.462

1.468

1.464

1.468

1.468

1.468

1.468

1.468

1.468

1.468

1.468

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1.468

1.468

1.468

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1.468

1.468

1.468

1.468

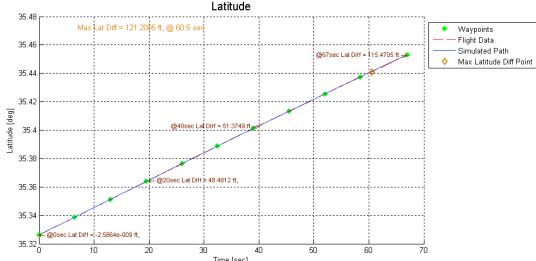
Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 11 Waypoints

Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

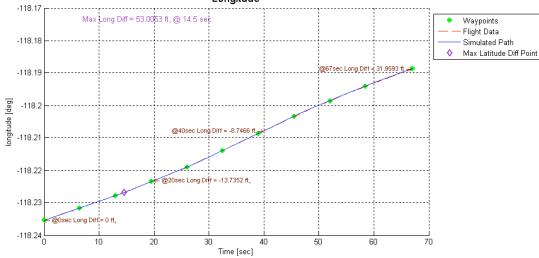
Using 11 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

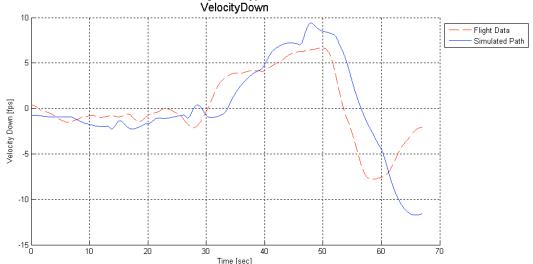
Using 11 Waypoints Longitude



Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

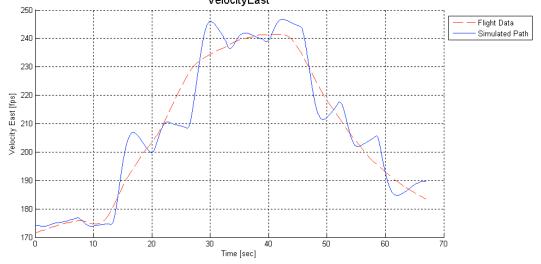
Using 11 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

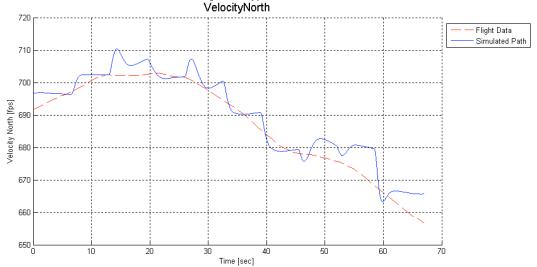
Using 11 Waypoints VelocityEast



Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

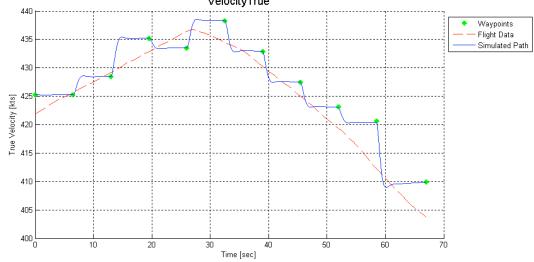
Using 11 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

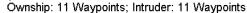
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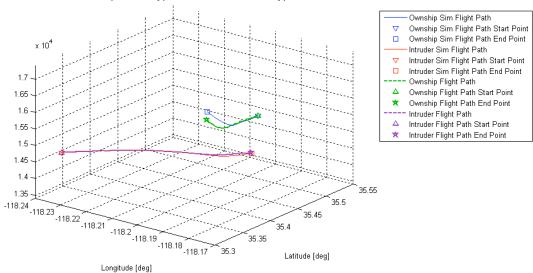
Using 11 Waypoints VelocityTrue

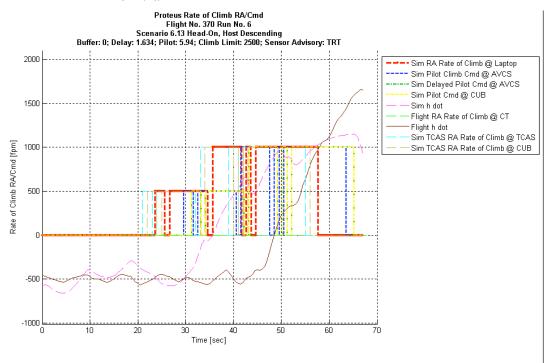


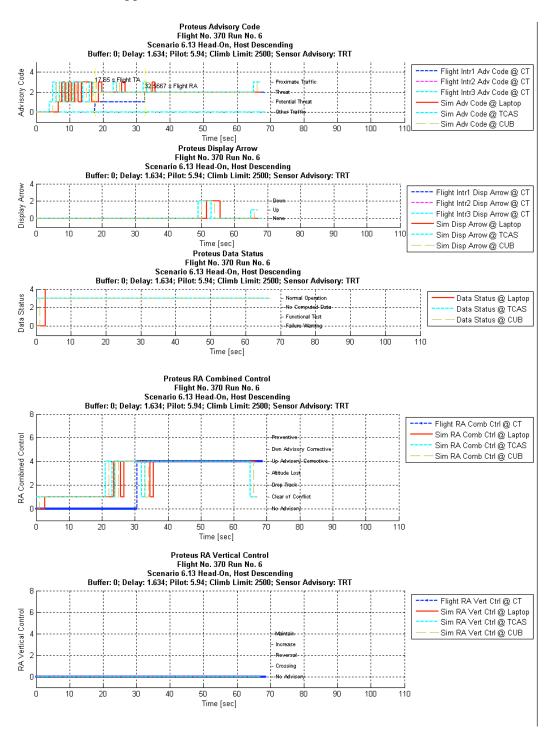
Proteus-Generic G-III 3-D Plot Flight No. 370 Run No. 6 Scenario 6.13 Head-On, Host Descending

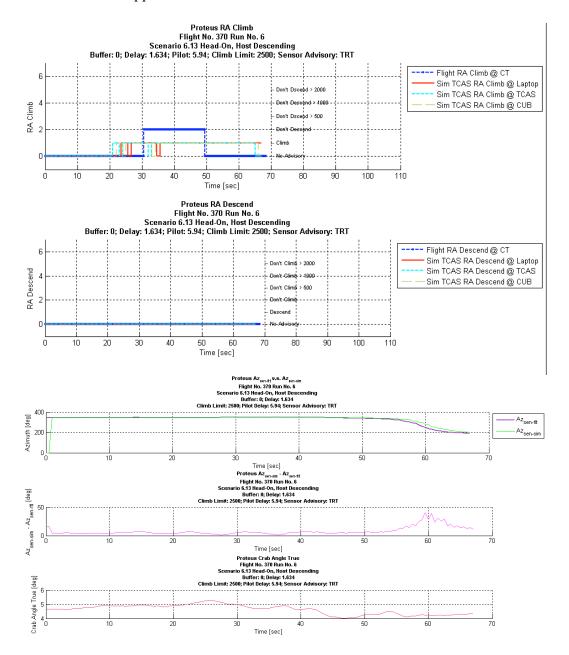
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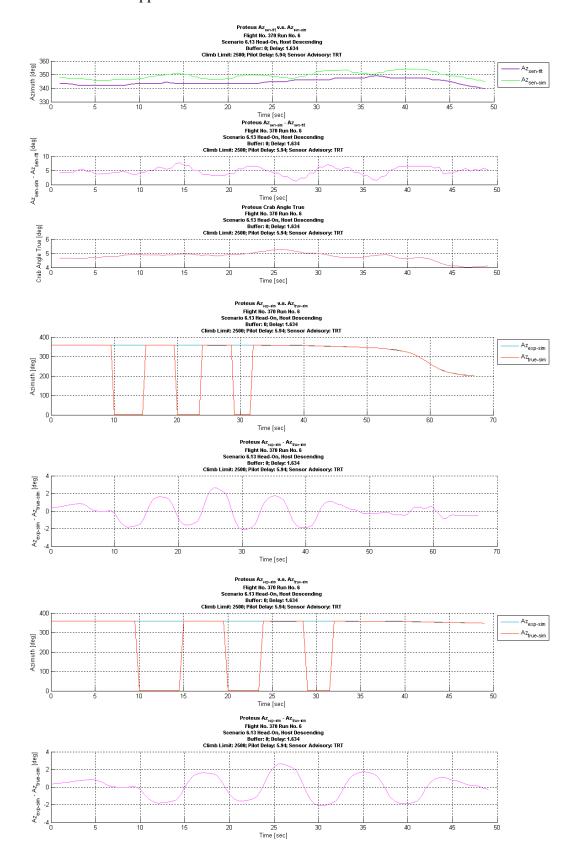


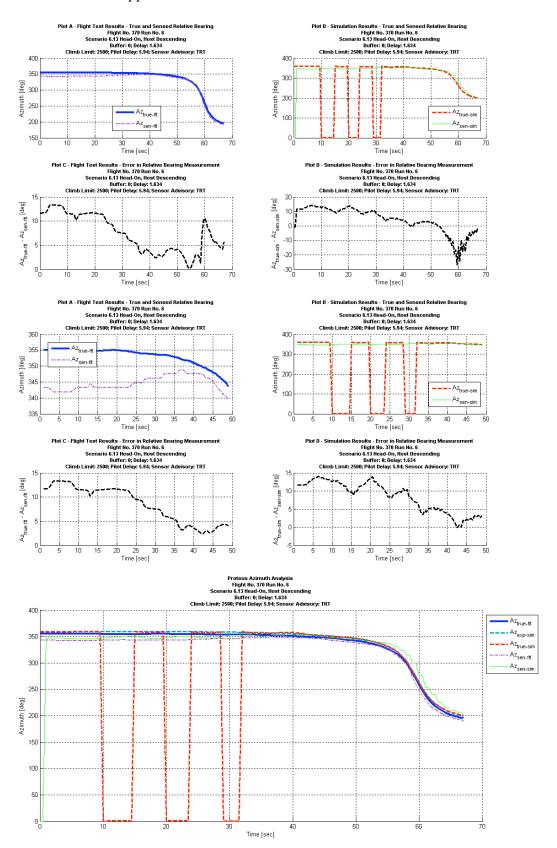


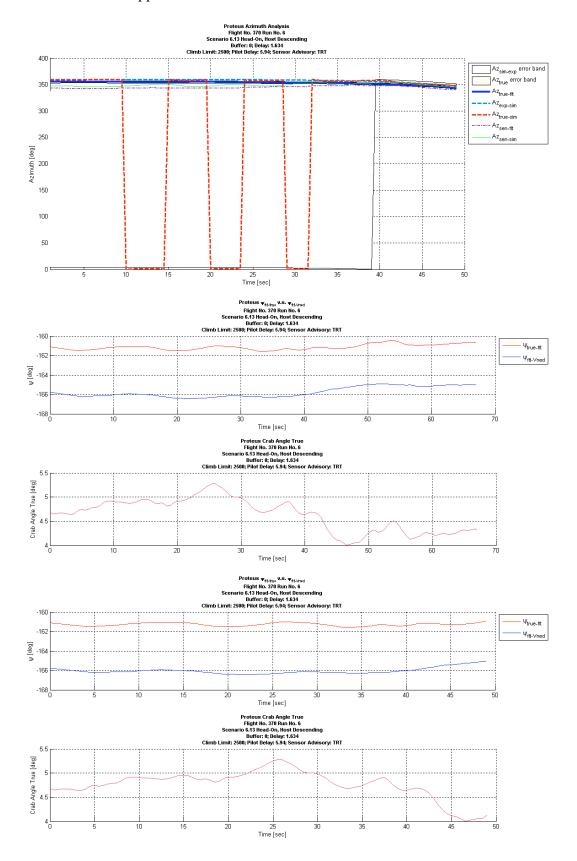


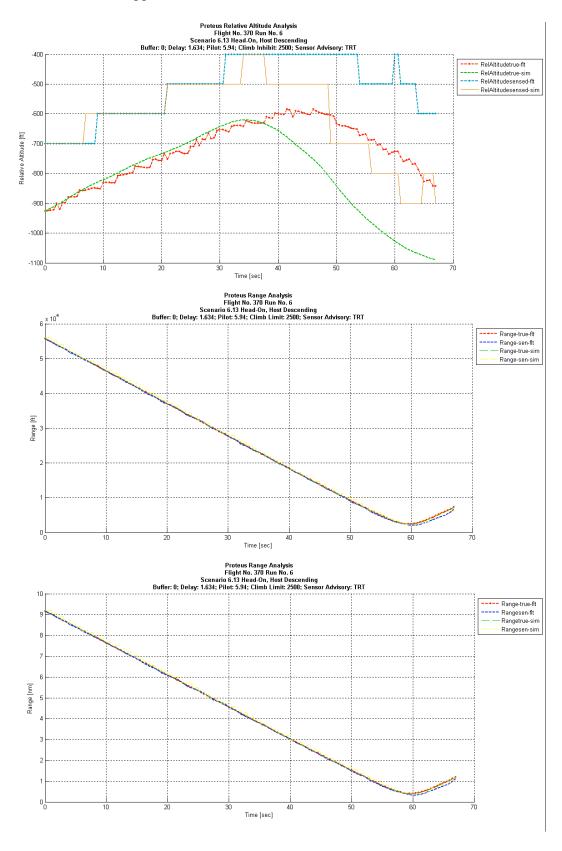






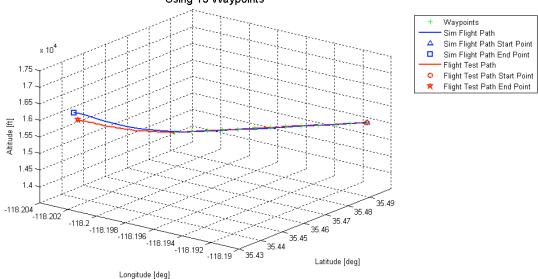




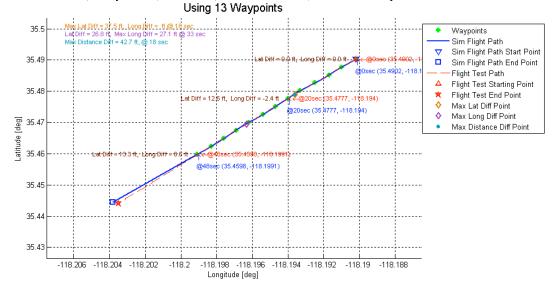


Flight 370 Run 7

Proteus 3-D Plot
Flight No. 370 Run No. 7
Scenario 6.14 Head-On, Host Descending
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT
Using 13 Waypoints

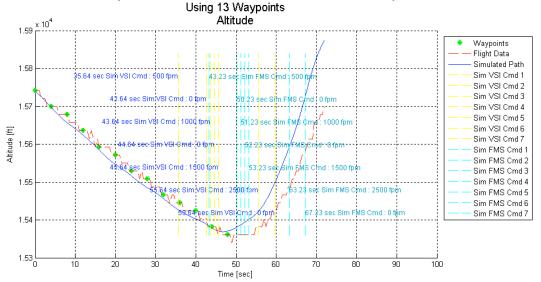


Proteus Flight Path Position Plot
Flight No. 370 Run No. 7
Scenario 6.14 Head-On, Host Descending
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



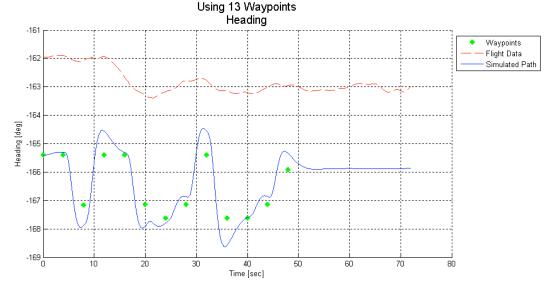
Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

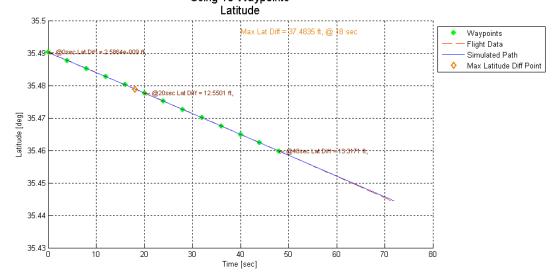
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT



Proteus Time History Plot Flight No. 370 Run No. 7

Scenario 6.14 Head-On, Host Descending

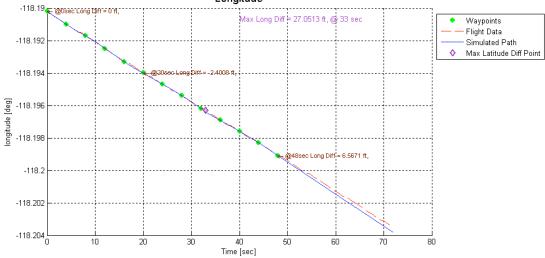
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 13 Waypoints



Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

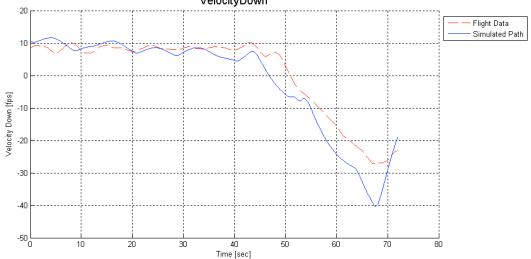
Using 13 Waypoints Longitude



Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

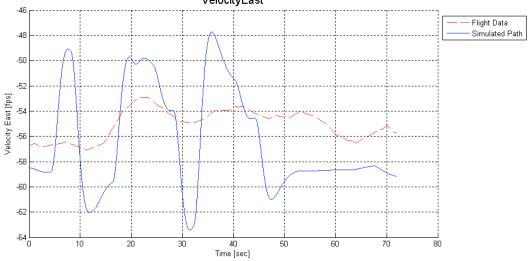
Using 13 Waypoints VelocityDown



Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

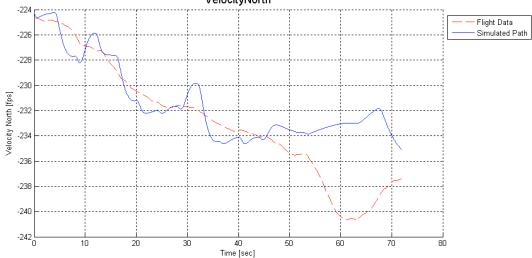
Using 13 Waypoints VelocityEast



Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

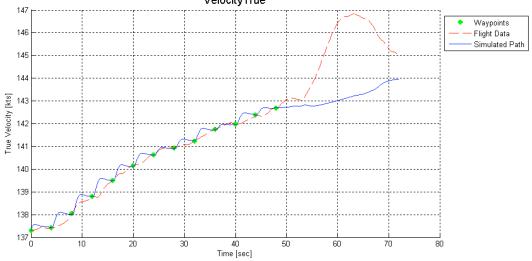
Using 13 Waypoints
VelocityNorth



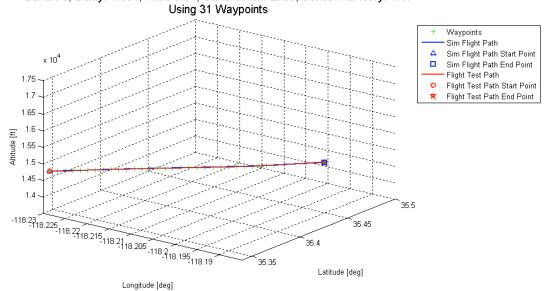
Proteus Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 13 Waypoints VelocityTrue

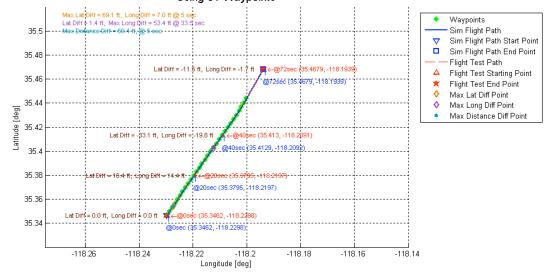


Generic G-III 3-D Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Inhibit: 2500; Sensor Advisory: TRT



Generic G-III Flight Path Position Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 31 Waypoints

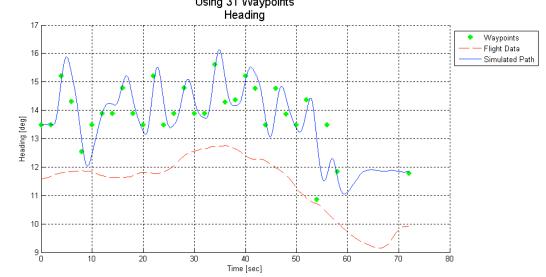


Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

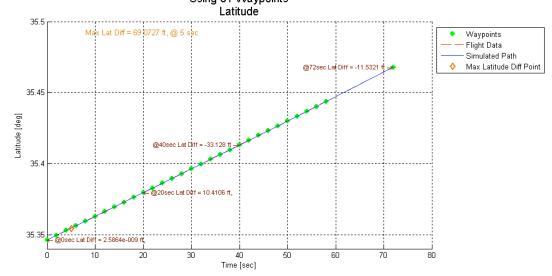
> Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 31 Waypoints



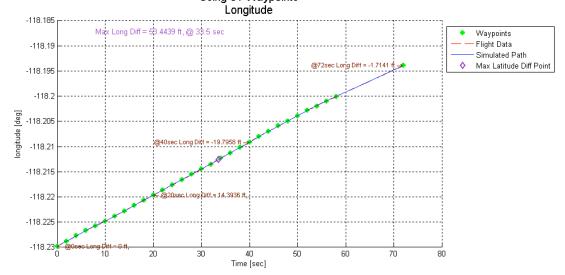
Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 31 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

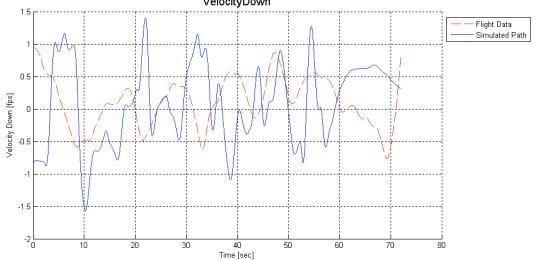
Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT Using 31 Waypoints



Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

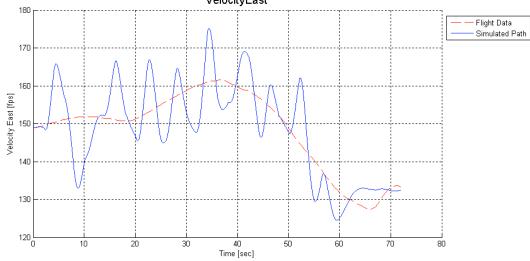
Using 31 Waypoints VelocityDown



Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

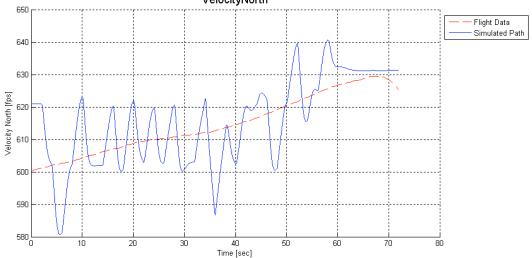
Using 31 Waypoints VelocityEast



Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

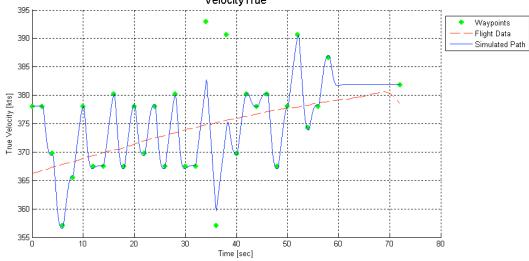
Using 31 Waypoints VelocityNorth



Generic G-III Time History Plot Flight No. 370 Run No. 7 Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

Using 31 Waypoints VelocityTrue



Proteus-Generic G-III 3-D Plot Flight No. 370 Run No. 7

Scenario 6.14 Head-On, Host Descending

Buffer: 0; Delay: 1.634; Pilot: 5.94; Climb Limit: 2500; Sensor Advisory: TRT

